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THE MINERAL INDUSTRY,

ITS STATISTICS, TECHNOLOGY AND TRADE

IN THE

UNITED STATES AND OTHER COUNTRIES.

Founded and Edited up to 1901 by the late R. P. ROTHWELL.
Present Editor, JOSEPH STRUTHERS, Ph. D.

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TO THE END OF

1901.

FOUNDED BY THE LATE

RICHARD P. ROTHWELL.

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Errata.

(Not including those of self-evident typography.)

Page 189, Table of the World's Copper Production.

United States	1900	270,588	274,933	should read	268,229	272,536		
United States	1901	266,716	270,998	should read	271,949	276,300		
Totals	1900	487,998	496,819	should read	485,634	494,422		
Totals	1901	523,162	532,148	should read	528,395	537,450		

Page 226, 3d line in table, "0.05, 1.1% Si," should read "0.05 to 0.1% Si."

Page 290, Table of Gold Production of the World.

Norway	1900	86,813	2,700.0	1,794,420	should read	87	2.7	1.794.
Norway	1901	86,813	2,700.0	1,794,420	should read	87	2.7	1.794.
Total Production	1900	12,614,633	392,331.8	260,743,830	should read			
		12,527,907	389,634.5	258,951,204				
Total Production	1901	12,812,792	398,507.0	264,840,477	should read			
		12,726,066	395,809.7	263,047,851				

Page 493, Title Fig. 1, "Canadian" should read "Orford."
Page 494, 21st line, omit "(See Fig. 1.)"
Page 495, 15th line, omit "from nickeliferous copper."
Plate facing p. 703, "Fig. A." should read "Fig.4."
Page 750, bottom line, omit "The table is illustrated in Fig. 3."
Page 751, "Fig. 3.—A Laboratory Slime Table" should read "Fig. 3.—Slime Sand Separator at the Portland Mill."
Page 754, 10th line from bottom, "Fig. 4" should read "Fig. 3."
Page 777, 12th line from bottom, "Fig. 3" should read "Fig. 4."
Page 778, 8th line from top, "Fig. 4" should read "Fig. 3."

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Linear.					Capacity.							
Inches to Millimeters.	Feet to Meters.	Yards to Meters.	Miles to Kilometers.		Drams to Cubic Centimeters.	Ounces to Millimeters.	Quarts to Liters.	Gallons to Liters.	Cubic Inches to Cubic Centimeters.	Cubic Feet to Cubic Meters.	Cubic Yards to Cubic Meters.	Bushels to Hectoliters.
25·4000	0·304801	0·914402	1·60935	= 1 =	3·70	29·57	0·94636	3·78544	16·387	0·02832	0·765	0·35242
50·8001	0·609601	1·828804	3·21869	= 2 =	7·39	59·15	1·89272	7·57088	32·774	0·05663	1·529	0·70485
76·2001	0·914402	2·743205	4·82804	= 3 =	11·09	88·72	2·83908	11·35632	49·161	0·08495	2·294	1·05727
101·6002	1·219202	3·657607	6·43739	= 4 =	14·79	118·30	3·78544	15·14176	65·549	0·11327	3·058	1·40969
127·0002	1·524003	4·572009	8·04674	= 5 =	18·48	147·87	4·73180	18·92720	81·936	0·14158	3·823	1·76211
152·4003	1·828804	5·486411	9·65608	= 6 =	22·18	177·44	5·67816	22·71264	98 323	0·16990	4·587	2·11454
177·8003	2·133604	6·400813	11·26543	= 7 =	25·88	207·02	6·62452	26·49808	114·710	0·19822	5·352	2·46696
203·2004	2·438405	7·315215	12·87478	= 8 =	29·57	236·59	7·57088	30·28352	131·097	0·22654	6·116	2·81938
228·6004	2·743205	8·229616	14·48412	= 9 =	33·28	266·16	8·51724	34·06896	147·484	0·25485	6·881	3·17181

Square.					Weight.				
Square Inches to Square Centimeters.	Square Feet to Square Decimeters.	Square Yards to Square Meters.	Acres to Hectares.		Grains to Milligrams.	Avoirdupois Ounces to Grams.	Avoirdupois Pounds to Kilograms.	Troy Ounces to Grams.
6·452	9·290	0·836	0·4047	= 1 =	64·7989	28·3495	0·45359	31·10348
12·903	18·581	1·672	0·8094	= 2 =	129·5978	56·6991	0·90719	62·20696
19·355	27·871	2·508	1·2141	= 3 =	194·3968	85·0486	1·36078	93·31044
25·807	37·161	3·344	1·6187	= 4 =	259·1957	113·3981	1·81437	124·41392
32·258	46·452	4·181	2·0234	= 5 =	323·9946	141·7476	2·26796	155·51740
38·710	55·742	5·017	2·4281	= 6 =	388·7935	170·0972	2·72156	186·62089
45·161	65·032	5·853	2·8328	= 7 =	453·5924	198·4467	3·17515	217·72437
51·613	74·323	6·689	3·2375	= 8 =	518·3914	226·7962	3·62874	248·82785
58·065	83·613	7·525	3·6422	= 9 =	583·1908	255·1457	4·08233	279·93133

1 chain	=	20·1169 meters.
1 square mile	=	259 hectares.
1 fathom	=	1·829 meters.
1 nautical mile	=	1853·27 meters.
1 foot=0·304801 meter,		9·4840158 log.
1 avoir. pound	=	453·5924277 gram.
15432·35639 grains	=	1 kilogram.

TABLES FOR CONVERTING METRIC TO UNITED STATES WEIGHTS AND MEASURES.

Linear.					Capacity.						
Meters to Inches.	Meters to Feet.	Meters to Yards.	Kilometers to Miles.		Milliliters or Cubic Centiliters to Fluid Drams.	Centiliters to Fluid Ounces.	Liters to Quarts.	Dekaliters to Gallons.	Hectoliters to Bushels.	Cubic Centimeters to Cubic Inches.	Cubic Meters to Cubic Feet.	Cubic Meters to Cubic Yards.
39·3700	3·28083	1·093611	0·62137	= 1 =	0·27	0·338	1·0567	2·6417	2·8375	0·0610	35·314	1·308
78·7400	6·56167	2·187222	1·24274	= 2 =	0·54	0·676	2·1134	5·2834	5·6750	0·1220	70·629	2·616
118·1100	9·84250	3·280833	1·86411	= 3 =	0·81	1·014	3·1700	7·9251	8·5125	0·1831	105·943	3·924
157·4800	13·12333	4·374444	2·48548	= 4 =	1·08	1·352	4·2267	10·5668	11·3500	0·2441	141·258	5·232
196·8500	16·40117	5·468056	3·10685	= 5 =	1·35	1·691	5·2834	13·2085	14·1875	0·3051	176·572	6·540
236·2200	19·68500	6·561667	3·72822	= 6 =	1·62	2·029	6·3401	15·8502	17·0250	0·3661	211·887	7·848
275·5900	22·96583	7·655278	4·34959	= 7 =	1·89	2·368	7·3968	18·4919	19·8625	0·4272	247·201	9·156
314·9600	26·24667	8·748889	4·97096	= 8 =	2·16	2·706	8·4534	21·1336	22·7000	0·4882	282·516	10·464
354·3300	29·52750	9·842500	5·59233	= 9 =	2·43	3·043	9·5101	23·7753	25·5375	0·5492	317·830	11·771

Square.					Weight.			
Square Centimeters to Square Inches.	Square Meters to Square Feet.	Square Meters to Square Yards.	Hectares to Acres.		Kilograms to Grains.	Hectograms to Ounces Avoirdupois	Kilograms to Pounds Avoirdupois.	Grams to Ounces Troy.
0·1550	10·764	1·196	2·471	= 1 =	15432·36	3·5274	2·20462	0·03215
0·3100	21·528	2·392	4·942	= 2 =	30864·71	7·0548	4·40924	0·06430
0·4650	32·292	3·588	7·413	= 3 =	46297·07	10·5822	6·61386	0·09645
0·6200	43·055	4·784	9·884	= 4 =	61729·43	14·1096	8·81849	0·12860
0·7750	53·819	5·980	12·355	= 5 =	77161·78	17·6370	11·02311	0·16075
0·9350	64·583	7·176	14·826	= 6 =	92594·14	21·1644	13·22773	0·19290
1·0850	75·347	8·372	17·297	= 7 =	108026·49	24·6918	15·43235	0·22505
1·2400	86·111	9·568	19·768	= 8 =	123458·85	28·2192	17·63697	0·25721
1·3950	96·874	10·764	22·2	= 9 =	138891·21	31·7466	19·84159	0·28936

The only material standard of customary length authorized by the U. S. Government is the Troughton scale, whose length at 59°.62 Fahr. conforms to the British standard. The yard in use in the United States is therefore equal to the British yard.

The only authorized material standard of customary weight is the Troy pound (5,760 grains) of the Mint. It is of brass of unknown density, and therefore not suitable for a standard of mass. It was derived from

the British standard Troy pound of 1758 by direct comparison. The British avoirdupois pound was also derived from the latter, and contains 7,000 grains troy.

The grain Troy is therefore the same as the grain avoirdupois, and the pound avoirdupois in use in the United States is equal to the British pound avoirdupois.

The British gallon = 4·54346 liters.

The British bushel = 36·3477 liters.

By the concurrent action of the principal Governments of the world an International Bureau of Weights and Measures has been established near Paris. Under the direction of the International Committee, two ingots were cast of pure platinum-iridium in the proportion of 9 parts of the former to 1 of the latter metal. From one of these a certain number of kilograms were prepared, from the other a definite number of meter bars. These standards of weight and length were intercompared, without preference, and certain ones were selected as International prototype standards. The others were distributed by lot to the different Governments and are called National prototype standards.

The metric system was legalized in the United States in 1866.

The International Standard Meter is derived from the Metre des Archives, and its length is defined by the distance between two lines at 0° Centigrade, on a platinum-iridium bar deposited at the International Bureau of Weights and Measures.

The International Standard Kilogram is a mass of platinum-iridium deposited at the same place, and its weight *in vacuo* is the same as that of the Kilogramme des Archives.

The liter is equal to a cubic decimeter of water, and it is measured by the quantity of distilled water which, at its maximum density, will counterpoise the standard kilogram in a vacuum, the volume of such a quantity of water being, as nearly as has been ascertained, equal to a cubic decimeter.

Long ton; 2240 lb. avoirdupois	=1016 kilogram.	Barrel of petroleum	= 42 gal.	= 1·59	hectoliter.
Short ton; 2000 " "	= 907·2 "	" " salt	= 280 lb.	=127	kilogram.
Pound avoirdupois	= 453·6 grams.	" " lime	= 200 "	= 90·720	"
Flask of Mercury=76½ lb. avoir.	= 34·7 kilograms.	" " natural cement,	= 300 "	=136·080	"
Troy ounce	= 31·104 grams.	" " Portland cement.	= 400 "	=181·440	"
Gallon	= 3·785 liters.	Gold coining value per oz. Troy	$20·6718=$0·6646 per gram.		
		Silver " " "	Troy $1·2929=$0·04157 "		

OFFICIAL UNITED STATES VALUES OF FOREIGN COINS, JULY 1, 1902.

Country.	Standard.	Unit.	Value in U. S. Gold.	Coins.
			cts.	
Argentina	Gold	Peso	96·5	Gold: argentine ($4·824) and ½ argentine. Silver: peso and divisions.
Austria-Hungary	Gold	Crown	20·3	Gold: former system—4 florins ($1·929), 8 florins ($3·858), ducat ($2·287), and 4 ducats ($9·149). Silver: 1 and 2 florins. Present system—Gold: 20 crowns ($4·052) and 10 crowns ($2·026).
Belgium	Gold	Franc	19·3	Gold; 10 and 20 francs. Silver: 5 francs.
Bolivia	Silver	Boliviano	39·2	Silver: boliviano and divisions.
Brazil	Gold	Milreis	54·6	Gold: 5, 10, and 20 milreis. Silver: ½, 1, and 2 milreis.
Canada	Gold	Dollar	100·0	
Central America...				
Costa Rica	Gold	Colon	46·5	Gold: 2, 5, 10, and 20 colons ($9·307). Silver: 5, 10, 25, and 50 centimos.
British Honduras	Gold	Dollar	100·0	
Guatemala, Honduras, Nicaragua, Salvador	Silver	Peso	38·2	Silver: peso and divisions.
Chile	Gold	Peso	36·5	Gold: escudo ($1·825), doubloon ($3·650), and condor ($7·300). Silver: peso and divisions.
China	Silver	Tael*	62·9	
Colombia	Silver	Peso	38·2	Gold: condor ($9·647) and double condor. Silver: peso.
Cuba	Gold	Peso	92·6	Gold: doubloon Isabella, centem ($5·017). Alphonse ($4·823). Silver: peso.
Denmark	Gold	Crown	26·8	Gold: 10 and 20 crowns.
Ecuador	Gold	Sucre	48·7	Gold: 10 sucres ($4·8665). Silver: sucre and divisions.
Egypt	Gold	Pound	494·3	Gold: pound (100 piasters), 5, 10, 20, and 50 piasters. Silver: 1, 2, 5, 10 and 20 piasters.
Finland	Gold	Mark	19·3	Gold: 20 marks ($3·859), 10 marks ($1·93).
France	Gold	Franc	19·3	Gold: 5, 10, 20, 50, and 100 francs. Silver: 5 francs.
German Empire	Gold	Mark	23·8	Gold: 5, 10, and 20 marks.
Greece	Gold	Drachma	19·3	Gold: 5, 10, 20, 50 and 100 drachmas. Silver: 5 drachmas.
Haiti	Gold	Gourde	96·5	Gold: 1, 2, 5 and 10 gourdes. Silver: gourde and divisions.
India	Gold	Pound†	486·65	Gold: sovereign (pound sterling). Silver: rupee and divisions.
Italy	Gold	Lira	19·3	Gold: 5, 10, 20, 50 and 100 lire. Silver: 5 lire.
Japan	Gold	Yen	49·8	Gold: 5, 10, and 20 yen. Silver: 10, 20, and 50 sen.
Liberia	Gold	Dollar	100·0	
Mexico	Silver	Dollar	41·5	Gold: dollar ($0·983), 2½, 5, 10, and 20 dollars. Silver: dollar (or peso) and divisions.
Netherlands	Gold	Florin	40·2	Gold: 10 florins. Silver: ½, 1, and 2½ florins.
Newfoundland	Gold	Dollar	101·4	Gold: 2 dollars ($2·027).
Norway	Gold	Crown	26·8	Gold: 10 and 20 crowns.
Persia	Silver	Kran	7·0	Gold: ¼, 1 and 2 tomans ($8·409). Silver: ¼, ½, 1, 2 and 5 krans.
Peru	Gold	Sol	48·7	Gold: libra ($4·8665). Silver: sol and divisions.
Portugal	Gold	Milreis	108·0	Gold: 1, 2, 5, and 10 milreis.
Russia	Gold	Ruble	51·5	Gold: imperial 15 rubles ($7·718) and ½ imperial, 7½ rubles ($3·859). Silver: ¼, ½, and 1 ruble.
Spain	Gold	Peseta	19·3	Gold: 25 pesetas. Silver: 5 pesetas.
Sweden	Gold	Crown	26·8	Gold: 10 and 20 crowns.
Switzerland	Gold	Franc	19·3	Gold: 5, 10, 20, 50 and 100 francs. Silver: 5 francs.
Turkey	Gold	Piaster	4·4	Gold: 25, 50, 100, 250, and 500 piasters.
United Kingdom	Gold	Pound	486·65	Gold: sovereign (pound sterling) and ½ sovereign.
Uruguay	Gold	Peso	103·4	Gold: peso. Silver: peso and divisions.
Venezuela	Gold	Bolivar	19·3	Gold: 5, 10, 20, 50, and 100 bolivars. Silver: 5 bolivars.

* Haikwan (Customs). † The sovereign is the standard coin of India, but the rupee ($0·324) is the money of account, current at 15 to the sovereign.

JOSEPH STRUTHERS.

FAC-SIMILE OF THE GOLD MEDAL AWARDED TO THE MINERAL INDUSTRY

BY THE

SOCIÉTÉ D'ENCOURAGEMENT POUR L'INDUSTRIE NATIONALE DE FRANCE,

IN RECOGNITION OF

ITS SERVICES TO THE WORLD'S INDUSTRY AND COMMERCE.

CONTRIBUTORS.

IT is impossible to name here all who have aided us in the collection of statistics and other information for the present volume, but we give in the following pages brief biographies of the most of those who have contributed special articles, in order that readers may appreciate the high professional standing of those who have assisted in the work.

Besides the contributors of special articles, however, the preparation of this volume has been aided by the courteous co-operation of many thousands of producers who have furnished statistics of their output, and by many persons prominent in various branches of the mineral industry who have given special information. Exceedingly valuable assistance has been furnished also by the officials of many railways in the United States and Mexico, and by the State geologists, commissioners of mines, and inspectors of mines in most of the States of the Union. The statisticians of foreign countries have been extremely courteous in their co-operation, by furnishing copies of their latest publications, often in manuscripts. Professional men and experts of the whole world have rendered exceedingly valuable assistance, as have also the officials of the United States Government at Washington and abroad, and have added greatly to the value of this work. Among the thousands who have thus aided us, and by their assistance made possible the publication of this volume, as well as its predecessors, it would be invidious to select names, and in making such an attempt we should not know where to draw the line, since the contributions of almost all have been indispensable. Consequently we have decided to limit ourselves to this general acknowledgment, relying upon the belief that each of our friends will feel amply repaid for his work in the knowledge that he has contributed to the preparation of a volume which is everywhere recognized to be of the highest value to the mineral industry of the world. This high appreciation has been generously and delicately expressed by the French "Société d'Encouragement pour l'Industrie Nationale," which, since the appearance of Vol. VI., has granted to THE MINERAL INDUSTRY and its founder, the magnificent gold medal of the society, which is voted to the work or the author of the work, which, during the six preceding years, has contributed most to the cause of the national industry.

ARGALL, PHILIP, was born in 1854, near Belfast, Ireland, and gained his first experience in mining at the Wicklow copper mines of that island. Since then he has been engaged in important mining and metallurgical work in Wales, England, France, New Zealand, Mexico, and elsewhere. He came to the United States early in 1887 as manager of La Plata Mining & Smelting Co., of Leadville, Colo. During the last nine years Mr. Argall has devoted his attention to the treatment of ores by the cyanide process, and has taken a leading position in this field. He designed the works of the Metallic Extraction Co., at Cyanide, Colo., in 1895, and managed them until February, 1901, when he resigned to resume the practice of consulting mining and metallurgical engineer. His success in the treatment of telluride ores on a large scale, has commanded much attention in metallurgical circles. For Volume VI. he wrote an article on "Cyaniding Telluride Ores," which is recognized as the most authoritative discussion of this subject published. To the present volume Mr. Argall contributes the paper "Zinc *versus* Electrolytic Precipitation."

BIRKINBINE, JOHN, was educated at the public schools, the Friends' High School, Philadelphia, the Hill School, Pottstown, and the Polytechnic College of Pennsylvania, and later entered the army service during parts of 1863 and 1864. Mr. Birkinbine has been actively engaged in many important hydrographic surveys and continues as consulting engineer in this specialty. Mr. Birkinbine has reported upon iron ore mines and others in most of the States, Canada and Mexico, and was a pioneer in recommending the establishment of blast furnaces on the Great Lakes. He was consulting engineer for the receivers of the Philadelphia & Reading Coal & Iron Co., and acted also as consulting engineer for Mr. Thomas A. Edison and for Messrs. Witherbee, Sherman & Co. At the present time he is the consulting engineer for the Cambria Steel Co., the Colorado Fuel & Iron Co., and other important corporations. Mr. Birkinbine is the expert on iron ore

and manganese ores for the United States Geological Survey, and in 1889 he prepared the report on iron ores for the Eleventh Census. For many years Mr. Birkinbine has been a member of the American Institute of Mining Engineers, and other prominent associations. He is president of the Franklin Institute of Philadelphia, as well as of the Pennsylvania Forestry Association. He served on the Jury of Award of the World's Columbian Exposition, of the Cotton States & International Exposition, and of the Pan American Exposition, etc. To the present volume he contributes the monograph, "Modern Improvements in the Manufacture of Pig Iron."

BREWER, WILLIAM M., was born in England, and acquired his education principally at the Philological School. He was a pioneer in the Black Hills of South Dakota, and learned practical mining and milling at the works of the Homestake Co. Mr. Brewer began practice as a consulting mining engineer and geologist in 1890, and examined and reported on the gold fields of Alabama in 1895, and reopened the old gold mine in Cherokee County, Georgia. He has made examinations in the Black Hills of South Dakota, in Arizona, Colorado, the Southern States, and British Columbia, and during 1901 traveled through British Columbia and southeastern Alaska on expert work. He is a member of a number of engineering societies, and has contributed to their proceedings and to the *Engineering and Mining Journal*. He contributes to the present volume the reviews for 1901 of gold and silver mining in Alaska and British Columbia, and copper mining in Canada.

CARPENTER, FRANKLIN R., was born in West Virginia. Educated as an engineer, with the degrees of M.A. and Ph.D., he began his mining work in the West Virginia coal and oil fields, and continued it in Colorado. In 1886, as Principal and Professor of Geology and Mining in the South Dakota School of Mines, he adapted the Kongsberg process of pyritic smelting to the South Dakota siliceous ores. For 10 years he was general manager of the Deadwood & Delaware Smelting Co. works, whose plant he designed and built. He designed also the plant for the Clear Creek Mining & Reduction Co., at Golden, Colo., of which company he is now general manager. Dr. Carpenter is a fellow of the Geological Society of America and of the American Institute of Mining Engineers. To the Institute he has contributed several papers, and other essays from his pen have treated of the geology and the mines of the Black Hills, and of pyritic smelting. To this volume Dr. Carpenter contributes the paper, "Pyritic Smelting."

DOUGLAS, JAMES, was born in Canada, but has made his home in the United States since 1875. His first experience in mining and metallurgy was acquired in trying to unravel the complicated affairs of an unsuccessful Canadian mining enterprise. He came to the States in order to take charge of copper works established in Phœnixville, Pa., for the utilization of local copper ores, whose supply, however, proved deficient; but he is best known through his connection with the copper industry of Arizona, with which he has been intimately associated almost since its initiation. He is a past president of the American Institute of Mining Engineers, and president of the Copper Queen Consolidated Mining Co., and of other Arizona concerns, including the Arizona & Southeastern Railroad Co. Such original work as he has done was chiefly in connection with the late eminent chemist, Dr. T. Sterry Hunt, in the field of the hydrometallurgy of copper. Mr. Douglas has contributed to the present volume the notes on the copper industry in Arizona.

DRAKE, FRANK, was graduated from the Michigan College of Mines in 1890, and afterward studied engineering and metallurgy at the Massachusetts Institute of Technology. He was employed at iron and copper mines in Michigan and at silver mines in Colorado until 1896, when he became superintendent of manganese mines in Russia for the Nicopol-Marioopol Mining & Metallurgical Co. While engaged with this organization he examined in its interest iron and manganese mines in various parts of Russia and the Caucasus. On returning from Russia in 1898 he became assistant manager of the War Eagle and Center Star gold-copper mines, B. C., resigning this position later to become chief engineer of the Oliver Iron Mining Co., and upon the formation of the United States Steel Corporation he became chief engineer of its iron mines. Mr. Drake contributes to this volume the paper, "The Nicopol Manganese District in Southern Russia."

JOHN BIKKINBINE.

PHILIP ARGALL.

FRANKLIN R. CARPENTER.

JAMES DOUGLAS.

PAUL DVORKOVITZ.

F. J. FALDING.

FRANK DRAKE.

AUGUST HECKSCHER.

W. H. HAMMON.

HENRY O. HOFMAN.

OTTOKAR HOFMANN.

WALTER RENTON INGALLS.

VICTOR LENHER.

JOHN B. C. KERSHAW.

ECKEL, EDWIN C., was graduated from the School of Civil Engineering, New York University, in 1896, and supplemented his college work with a post-graduate course in geology under Prof. J. J. Stevenson. In 1899 he became connected with the New York State Museum, and received an appointment as Assistant in Geology in 1900. Mr. Eckel has published reports on the cements of New York State, on the quarry industry, the emery deposits of Westchester County, N. Y., and on several minor economic products. He has also reported, for the U. S. Geological Survey, on the clays of western Mississippi and Tennessee, and has published a number of papers, chiefly on cement technology. Mr. Eckel is a member of the American Society of Civil Engineers, and of the Society of Chemical Industry, and to the present volume he contributes the article on "The Slag Cement Industry in the United States during 1901."

DVORKOVITZ, PAUL, in 1877-78 was appointed sanitary chemist to the hospital of the Princess of Oldeburg in the Russo-Turkish war. Afterward he studied chemistry at the University of Moscow, and in 1883 he took the position of technical manager of an oil refinery at Baku. There he discovered a method of utilizing the soda and acid by-products obtained in course of refining, and invented a special still for continuous distillation. Later, in England, Mr. Dvorkovitz worked to develop the use of solar oil for enriching water gas, and he invented an apparatus for gasifying oil and producing aromatic hydrocarbons. Five years ago he built for the Mineral Oils Corporation in London the first refinery in England, and prepared all the plans for another large refinery erected by the Shell Transport & Trading Co., Ltd., in Borneo. In 1899 he started the *Petroleum Review*, and in 1900, the *Oil World*. In 1900 Mr. Dvorkovitz was instrumental in forming the petroleum congress in Paris, in August, which resulted in the establishing of a permanent commission for organizing international petroleum congresses every two years in the future, with a central committee in Paris, and local committees all over the world. Mr. Dvorkovitz contributes to this volume the paper, "Petroleum."

FALDING, F. J., was born in England and was educated at Amersham Hall, London, and at the Bergakademie at Freiberg in Saxony, although he did not graduate from the latter. In 1878-79 he made a study of the Canadian apatite deposits, and in 1880 returned to Europe, where he studied the manufacture of sulphuric acid and fertilizers in England and Germany. In 1881 he returned to Canada and unwatered the Capelton pyrites mines, now worked by the Nichols Chemical Co. From 1882 to 1886 he practiced as a mining engineer, with headquarters in New York, making a specialty of pyrites and phosphate mining. In 1888 he entered the employ of the Grasselli Chemical Co. as engineer, in charge of its mines, becoming in 1890 the chief engineer. During this time he designed the company's new works at East Chicago, Ill. In 1889 he was one of the charter members and first directors of the Canadian Institute of Mining Engineers. In 1895 he established himself in New York as a consulting chemical engineer, since when he has constructed and rebuilt many sulphuric acid plants in various parts of the United States. He contributes to this volume the paper, "Progress in the Sulphuric Acid Industry in 1901."

HECKSCHER, AUGUST, was born at Hamburg, Germany, and educated in Germany and Switzerland. He was actively connected with the anthracite coal mining industry in the United States from 1868 to 1882, and since 1881 he has been engaged in the zinc mining and manufacturing industry in New Jersey, Pennsylvania, Illinois, Wisconsin and Missouri. At present he is general manager of the New Jersey Zinc Co. Mr. Heckscher contributes to this volume the review notes on the zinc industry of New Jersey.

HOFMAN, H. O., was born in 1852 at Heidelberg, Germany. He studied at the Bergakademie at Clausthal, where he graduated in 1877 in mining engineering and metallurgy. He was then appointed chemist and assistant at the smelting and refining works at Lautenthal in the Harz. In 1881 he came to the United States and was employed successively at Mine La Motte, in Missouri, at the Argentine smelting and refining works of the Consolidated Kansas City Smelting & Refining Co., and as metallurgist of the Delaware Lead Co., in Philadelphia. When the last named works were closed he went to Colorado, and after running the Rico smeltery for a short time went to Park City, Utah, to study the amalgamation and lixiviation of silver ores at the Ontario mill. After a

short time spent in charge of a smeltery in Mexico he was appointed assistant to Prof. Richards at the Massachusetts Institute of Technology in Boston; from there he went to the School of Mines of South Dakota as professor of metallurgy and assaying, where he remained until called back to the Massachusetts Institute of Technology to the professorship of metallurgy, which he now holds. Dr. Hofman has made numerous contributions to technical literature, his most important work being the admirable treatise on *The Metallurgy of Lead*. For his paper on the "Dry Assay of Tin Ores" the degree of Ph.D. was conferred on him by the University of Ohio. For the present volume he has contributed the article "Progress in the Metallurgy of Lead."

HAMMON, W. H., was born in 1860. He was graduated at Allegheny College, Meadville, Pa., in 1881, and afterward spent one year in post-graduate work in Columbia University, Washington, D. C., and two years in advance physical and mathematical work at Cornell University, Ithaca, N. Y. In the early eighties he was employed on the engineering corps of the Standard Oil interests in the Bradford and adjacent fields, and was afterward connected with the United States Weather Bureau, serving as observer at Cleveland and St. Louis, and as Forecast Official in St. Louis and San Francisco. In January, 1899, he was appointed professor of meteorology in the Weather Bureau, which position he shortly afterward resigned to accept a position as assistant to the general manager of the Philadelphia Company, at Pittsburg, Pa., which position he still holds. Mr. Hammon contributes to this volume the paper "Natural Gas."

OLIPHANT, F. H., was born at Uniontown, Fayette County, Pa., August 30, 1845, and was graduated from the Polytechnic College of Pennsylvania, at Philadelphia, in 1868, receiving the degree of civil engineer. For several years after graduation Mr. Oliphant was employed by the Pennsylvania Railroad in construction work, and later in the operation of bituminous coal mines in western Pennsylvania and Kentucky. For the past fifteen years he has been employed as geologist in the petroleum and natural gas fields of the United States and foreign countries, and during the last five years of this period he has compiled the reports on petroleum and natural gas for the United States Geological Survey. To the present volume Mr. Oliphant contributes the reviews of the natural gas and petroleum industry in the United States during 1901.

HOFMANN, OTTOKAR, was born in 1843 at Rusberg, in Austria-Hungary, and educated at the Realschule and Polytechnic Institute in Vienna, and the Bergakademie at Freiberg, graduating from Freiberg in 1866. In 1867 Mr. Hofmann came to the United States, entering the assay office of Guido Kuestel in San Francisco as partner as his first venture. Mr. Hofmann has been largely identified with leaching processes for the extraction of gold and silver from ores. In 1868 he erected at La Dura, Sonora, Mexico, the first lixiviation works operated in North America, following its success with the construction of other works at La Trinidad and San Marcial, Sonora, and Trinufo, Lower California. He has served as metallurgist for various amalgamation and chlorination mills in Nevada and California, and since 1880 he has been occupied almost exclusively in hydrometallurgy, having been engaged successively at St. Louis, Mo. (1882-3); Cusihuiriachic, Chihuahua (1885); Yedras, Sinaloa (1886-7); Cusihuiriachic (1887); Parral, Chihuahua (1888); Cusihuiriachic (1890-94); Sombrerete and Parral (1894). In 1895 Mr. Hofmann took charge of the leaching department of the Consolidated Smelting & Refining Co., at Argentine, Kan., and in 1897 he displaced the Hunt & Douglas process then in use, by a process which freed, in one operation, copper sulphate solutions from iron, arsenic, antimony, and other impurities. Mr. Hofmann is now consulting chemist for the American Smelting & Refining Co., and cousulting metallurgist for the Avino mines of Mexico, and chemical director of the United Zinc & Chemical Co., of Kansas. Mr. Hofmann has contributed largely to metallurgical literature, chiefly through the medium of the *Engineering and Mining Journal* and the *Transactions of the American Institute of Mining Engineers*. Supplementing his excellent article in THE MINERAL INDUSTRY, Vol. VIII., Mr. Hofmann contributes to the present volume the paper "Progress in 1900 and 1901 in the Manufacture of Blue Vitriol by Hofmann's Method."

INGALLS, WALTER RENTON, was born at Lynn, Mass., in 1865, and was graduated from the

Massachusetts Institute of Technology, in 1886. In 1886-90 he was engaged in mining at Leadville and elsewhere in Colorado. In 1890-92 he was assistant editor of the *Engineering and Mining Journal*, resigning that position to go to Mexico to open tin mines in the State of Durango for the Pittsburg & Mexican Tin Mining Co. In 1893 and 1894 he established himself in New York, and visited professionally various mining districts in the United States, Canada, Belgium, Germany and Poland, devoting himself especially to the metallurgy of zinc. During a part of 1894 he had charge of the operations of the Illinois Phosphate Co., in Florida, and later in the year became connected with the Gold & Silver Extraction Co. of America, Ltd., as metallurgist. In 1895 he was manager of a cyanide works at Cripple Creek, Colo., and in 1896 of copper-matte smelting works in Durango, Mexico, returning to New York in 1897. He was assistant editor of THE MINERAL INDUSTRY, Vols. V., VI. and VII., and is now located in Boston, Mass., as consulting engineer. For this volume he contributes the paper, "The Progress in the Metallurgy of Zinc in the United States during 1901."

KERSHAW, JOHN B. C., was born at Southport, Eng., and was educated at Bickerton House School, Southport, and at Owens College, Manchester. In 1879 Mr. Kershaw entered the Sutton Lodge Chemical Works, St. Helens, Eng., and remained there for twelve years, rising in this period to the position of chief chemist and assistant manager. In 1892 Mr. Kershaw went to Germany and pursued his studies of chemistry and allied sciences at Bonn University. Since 1896 he has been engaged in practice as consulting chemist and as a technical journalist in London, and has devoted himself especially to work relating to electro-chemical processes and industries. He is a member of several chemical and other societies, and is also on the staff of abstractors for *The Journal of the Society of Chemical Industry* and for *Science Abstracts*. Mr. Kershaw has written numerous articles in recent years upon electro-chemical and electro-metallurgical subjects, and is the translator and editor of Dr. Neumann's German work on *Electrolytic Methods of Analysis*. To the present volume he contributes the articles, "Progress in the Aluminum Industry in 1901," "Chlorates and Hypochlorites in 1901," and the general review of the "Progress in the Electro-Chemical and Electro-Metallurgical Industries in 1901."

LENHER, VICTOR, was graduated in chemistry in 1893 from the University of Pennsylvania, and for three years following he was assistant to Prof. W. B. Rising in the chemical department of the University of California. From 1896 to 1898 he was engaged in pursuing special studies in chemistry, mineralogy and geology at the University of Pennsylvania, receiving the degree of Ph.D. from that institution in 1898. Dr. Lenher has been a regular contributor to various chemical journals. He was on the staff of instruction in chemistry at Columbia University from 1898 to 1900, and is at present assistant professor of general and theoretical chemistry at the University of Wisconsin. He contributes to this volume the article, "Rare Elements."

LEWIS, FREDERICK H., studied civil engineering at the University of Pennsylvania, graduating in 1878. He then became heliotroper on the United States Coast Survey, serving during the summer of 1878, and for three years afterwards was assistant engineer of the construction department of the Pennsylvania Railroad Co.'s lines west of Pittsburg. From 1882 to 1885 he was superintendent of bridges and buildings of the Northern Pacific Railway, being situated at St. Paul, Minn., and he was also in charge of the location of the company's terminal lines between St. Paul and Minneapolis. In 1885 and 1886 he was resident engineer of the South Pennsylvania Railroad, at Sideling Hill tunnel, Fulton County, Pa. From 1886 to 1893 he was an Eastern manager of the Pittsburg Testing Laboratory at Philadelphia. Since 1893 he has been practicing as consulting engineer at Philadelphia, and has also been consulting engineer for the firm of Booth, Garrett & Blair, in their department of physical tests and inspection. He is manager and chief engineer of the Virginia Portland Cement Co., and contributes to this volume the paper on "The Cement Industry in the United States during 1901."

MCILHINEY, PARKER C., was born in 1870, at Jersey City, N. J., and in 1892 he was graduated from the School of Mines, Columbia College, in the course of chemistry, receiving in 1894 the degree of Ph.D. for special work in chemistry and physics. From 1894

until 1900 he was connected with the Departments of Chemistry and Metallurgy, Columbia University, and, in addition to general chemical practice he has given considerable time to the manufacture of glass, metal, enamel and pottery art works. Dr. McIlhiney contributes to this volume the paper, "The Manufacture of White Lead."

MATHER, HENRY A., was born March 31, 1870, and attended Rutgers College, Scientific School, for two years, completing his education with a special course in chemistry at Johns Hopkins University, graduating in 1891. From 1893 to 1899 he was at first vice-president, later president, of the Greenpoint Chemical Works of Brooklyn, N. Y., which works was the pioneer in the United States in recovering cyanides from "gas mass" and spent purifying material. Mr. Mather devised several processes which were used in connection with the manufacture of iron oxide for gas purification and recovery of by-products from spent oxide. From 1899 to 1901 he was secretary, and during part of 1900 metallurgist in charge of the initial smelting operations of the Verde Queen Copper Co., at Jerome, Ariz. Mather has made contributions on technical subjects to the *American Gas Light Journal* and the *Engineering and Mining Journal*, and since April, 1902, has been assistant on the editorial staff of the present volume.

MATHEWS, JOHN ALEXANDER, was born in Washington, Pa., May 20, 1872, and was graduated from Washington and Jefferson College in 1893 with the degree of B.Sc. Later he entered Columbia University as a graduate student in chemistry, and received therefrom the degrees of M.A. and Ph.D. He was awarded by Columbia University, the University Fellowship in Chemistry in 1897, and the Barnard Fellowship for the Encouragement of Scientific Research in 1900, 1901 and 1902, and by the Iron and Steel Institute of Great Britain, the Andrew Carnegie Research Scholarship in 1901. From 1897 to 1900 Dr. Mathews was instructor in the Department of Chemistry of Columbia University. He resigned in 1900 to follow research work on alloys in the laboratory of Prof. Sir William C. Roberts-Austen, London, which has since been continued at Columbia University under Prof. Henry M. Howe. President McKinley appointed Dr. Mathews a member of the United States Assay Commission in 1900, and the first Andrew Carnegie gold medal for research was awarded him by the Iron and Steel Institute in 1902. Dr. Mathews is a member of the American Chemical Society, being the secretary and treasurer of the New York section. He has written many scientific articles, and for the present volume he has contributed the paper "Alloys as Solutions."

MEMMINGER, C. GUSTAVUS, was born at Charleston, S. C., in 1864, and began work as mining engineer in the phosphate industry of South Carolina. He took an active part in the mineral development of the South, and when the Florida phosphate deposits were opened he was prominent in the furthering of the new industry there. After building and successfully operating the largest pebble phosphate mining plant in Florida, Mr. Memminger, in 1900, moved to Nashville, Tenn., from whence he removed to Florida in 1901, and is at present actively engaged in the development and mining of phosphates. Mr. Memminger contributes to this volume the paper, "Progress in the Phosphate Mining Industry in the United States during 1901."

MILLER, EDMUND H., was graduated from the chemical course of Columbia School of Mines in 1891, and received the degree of Doctor of Philosophy from Columbia University in 1894. At present, Dr. Miller is Adjunct Professor of Analytical Chemistry and Assaying at Columbia University, and is giving special attention to inorganic chemistry and assaying. Prof. Miller is the author of "Calculations of Analytical Chemistry and Notes on Assaying" (with Dr. P. de P. Ricketts), and has written numerous articles in the chemical journals on the results of his original work in chemistry. To the present volume Dr. Miller contributes "Reviews of Analytical Chemistry Relating to Barium, Boron, Bismuth, Chromium, Gold, Manganese, Potassium, Silver, Sulphur and Tin."

NEWLAND, DAVID H., was graduated from Hamilton College in 1894, and for three years thereafter was a student of geology and related sciences at the Universities of Munich, Heidelberg and Columbia. In 1897 and 1898 he was employed by the State of New York mapping the geology of portions of the Adirondack Mountains, the results

JOHN A. MATHEWS.

F. H. LEWIS.

EDMUND H. MILLER.

FRANK NICHOLSON.

F. H. OLIPHANT.

ROBERT H. RICHARDS.

F. DANVERS POWER.

WILBUR E. SANDERS.

HEINRICH RIES.

ALBERT SAUVEUR.

FREDERICK SCHNIEWIND.

VINCENTE SPIRER.

WALTER HARVEY WEED.

TITUS ULKE.

of this work appearing recently in the Eighteenth Annual Report of the State Geologist. He has been engaged from time to time in other geological investigations, particularly in determining the petrographical relations of metamorphosed rocks, and has contributed to scientific journals. For the past two years, until April, 1902, Mr. Newland has been connected with THE MINERAL INDUSTRY as assistant on the editorial staff.

OBALSKI, J., was born in France in 1852, and studied at the Ecole des Mines at Paris; after graduation he occupied several positions in connection with the mining industry in France and Spain, and visited various mining districts in those countries and Belgium and Portugal. In 1881 he was called by the government of the Province of Quebec to fill the position of mining engineer and inspector of mines, which post he still occupies. He has contributed to the present volume notes on asbestos, chrome ore, copper ore and mica mining in Quebec.

POWER, FREDERICK DANVERS, was born at Lee, England, in 1861. He received his technical training in Swansea, South Wales; at the Royal School of Mines, London, and at the Bergakademie of Clausthal, Germany. He has travelled in South America and North Africa, but has spent most of his professional life in various parts of Australasia and the South Seas, having arrived in Victoria in 1885. He has held various appointments for British and Colonial companies, and has contributed several scientific papers to English and Colonial journals and transactions of scientific societies. He is also the author of a "Pocketbook for Miners and Metallurgists," published by Messrs. Crosby, Lockwood & Son. He has been on the council of the Australasian Institute of Mining Engineers from its foundation, and has acted both as vice president and president; he was formerly examiner of Mining at the University of Melbourne; vice-president of the New South Wales Chamber of Mines, and is a life member of the American Institute of Mining Engineers, the Institute of Mining and Metallurgy and the Royal Geological Society, London. For the present volume he contributes articles on "Phosphates of Ocean and Pleasant Islands (Gilbert and Marshall Groups)," and "Notes on the Nickel, Chrome and Cobalt Deposits in New Caledonia."

PRATT, JOSEPH HYDE, was born at Hartford, Conn., on February 3, 1870, and was graduated from Sheffield Scientific School, Yale University, with the degree of Ph.B., in 1893, and Ph.D. in 1896. Mr. Pratt was instructor in mineralogy at Yale from 1895 to 1897. Since then he has acted as State Mineralogist of North Carolina, and field assistant of the United States Geological Survey since 1898, besides acting as lecturer on mineralogy for the University of North Carolina. He has contributed a number of articles on mineralogy, geology and chemistry to scientific magazines, and is a member of several geological, geographical and engineering societies. Dr. Pratt contributes to the present volume the review of gold mining in North and South Carolina, and the paper "Progress in the Corundum and Emery Industries during 1901."

RICHARD, ROBERT HALLOWELL, professor of mining and metallurgy at the Massachusetts Institute of Technology, was born in 1844 at Gardiner, Me. He graduated in 1868 from the Massachusetts Institute, being a member of its first class, and became assistant in chemistry in the corps of instruction, passing successively to the post of instructor, assistant professor of chemistry, professor of mineralogy and assaying, professor of mining engineering, and in 1884 to his present professorship of mining and metallurgy. Under his administration the mining and metallurgical laboratory, which was the first of its kind in an educational institution, has been developed to a high degree of excellence, and has been a model for similar laboratories in other colleges. In addition to his professional duties, Prof. Richards has been actively engaged as a consulting engineer in mining and metallurgical work, and has been the inventor of several ingenious devices, which have found extended use in practice. He has contributed many valuable papers to the technical press, and to the transactions of various scientific societies. His most recent work on the principles of ore dressing is the admiration of the entire body of engineers engaged in that branch of metallurgy. To this, as in previous volumes, he has contributed the reviews "Progress in Ore Dressing" and "Progress in Gold Milling."

RIES, HEINRICH, Ph.B., A.M., Ph.D., was graduated in 1892 from Columbia College,

School of Mines, New York City. After his graduation he was employed as assistant geologist on the New York State Geological Survey, and during the World's Fair at Chicago he was assistant director of the New York scientific exhibit. He has prepared much valuable data on the clays of New York State, and in a special trip made to Europe to investigate the foreign clay-working industry, he studied at the University of Berlin the German methods for the laboratory investigation of clays. In 1895 he was judge of clays at the Cotton States Exhibition, and member of the jury of awards at the Pan-American Exposition in 1901. Dr. Ries has written a number of papers on economic geology, and has prepared special State reports on the clays of New York, Michigan, Alabama, North Carolina, Louisiana, Maryland and New Jersey. From 1898 to 1902 he has been instructor in economic geology in Cornell University, Ithaca, N. Y., receiving in the latter year the position of assistant professor. Dr. Ries is an associate editor of the *Geologische Centralblatt*. To this volume he contributes the paper, "Fire Clays and Their Manufacture into Refractory Materials" and "Review of Literature of Clays and Clay Products."

ROSSI, AUGUSTE J., was born in Paris in 1839. In 1855 he was graduated from the University of France, and he received his degree of civil and mining engineer from the Ecole Centrale in 1859. Soon afterward he came to the United States, of which he has long been an adopted citizen. Mr. Rossi, in the course of his professional practice, has been with the Morris & Essex Railroad, with the Boonton blast furnaces and with the New York Ice Machine Co. For the past eight years he has devoted himself particularly to electro-metallurgy, and as consulting mining engineer has been engaged in the study of the metallurgy of titanium. He is a member of the American Institute of Mining Engineers and of the American Chemical Society, and various articles from his pen have appeared in the published proceedings of these societies, and in other technical publications. To this volume Mr. Rossi contributes the paper, "The Manufacture of Liquefied Carbonic Acid Gas."

SANDERS, WILBUR E., was graduated from Columbia College School of Mines, as mining engineer in 1885, and following graduation spent several years working in every manual capacity in various mines, mills and metallurgical establishments of the West, to gain practical experience. As examining engineer Mr. Sanders has travelled over and examined a large part of the metalliferous region of the West, and has both superintended and operated properties in Idaho, South Dakota, Washington, British Columbia, Colorado and Montana; in the latter State he was in charge of the exploiting of the noted East Pacific mines. His latest connection, that of geologist to the Amalgamated Copper Co., of Butte, Mont., he resigned, recently, to devote himself to his forthcoming work on "Mine Timbering and the Support of Earthworks." His contribution to the present volume of the mineral industry is a preliminary paper on this subject.

SAUVEUR, ALBERT, studied four yours at the Ecole des Mines at Liége, Belgium, and then at the Massachusetts Institute of Technology, where he was graduated in 1889. After one year in the chemical laboratory of the Pennsylvania Steel Co., at Steelton, Pa., he became connected with the South Chicago works of the Illinois Steel Co., with which he remained six years, most of the time in charge of the experimental laboratory. Since February, 1897, he has been proprietor and manager of the Boston Testing Laboratories at Boston, and is now assistant professor at Harvard University, and editor of *The Metallographist*. From 1898 to 1900 he was lecturer on metallography at the Massachusetts Institute of Technology. Mr. Sauveur is a member of several scientific societies, and has been a contributor to numerous technical publications. He has a world wide reputation as an expert in his specialty, the investigation of the micro-structure of metals, and its bearing upon their technology. Mr. Sauveur contributes to this volume the paper, "The Progress in Metallography in 1901."

SCHNIEWIND, FREDERICK, was born at Bochum, Westphalia, in 1861. He studied at the institutes of technology at Charlottenburg and Munich and at the universities of Berlin, Munich and Heidelberg, receiving the degree of Ph.D. at the latter university. He then entered the laboratory of a Westphalian blast furnace and subsequently had

charge of analytical laboratories at Cleveland, O., and Crystal Falls, Mich. Since its inception he has been connected with the United Coke and Gas Co., which builds and operates by-product coke ovens, especially of the Otto-Hoffmann type. He adapted by-product coke ovens to the manufacture of illuminating gas and has made a number of improvements in their construction. He is the author of numerous articles on coal distillation in coke-ovens, and to the present volume he contributes the paper, "Manufacture of Coke in the United States, with Special Reference to the Markets for By-Products."

SPIREK, VINCENTE, was born in 1852, at Bubovice, near Prag, Bohemia, and was graduated from the Bergakademie at Pribram in 1876. He entered at once into active mining and in 1878-1879 became an officer of the government mining bureau in Bosnia, Herzegovina. He was employed under Exeli in Idria, and from 1876 to 1890 he was associated there with Cermak in the remodeling of the works and the design of the well-known Cermak-Spirek quicksilver furnace. After service as an officer in the army in Bosnia and Herzegovina he resigned his position of Oberhuetteningenieur in the State Mines Direction to take charge of the quicksilver works at Monte Amiata, Italy. Mr. Spirek has received several government medals in recognition of his special work as an engineer, and he has written a number of technical articles. To the present volume he has contributed notes on the working results of the Cermak-Spirek furnace on quicksilver ores and the paper, "The Cermak-Spirek Furnace for Roasting Zinc Ores."

STRUTHERS, JOSEPH, was born at New York City in 1865, and attended the School of Mines, Columbia College (now Columbia University), graduating therefrom in the course of chemistry in 1885, and in 1895, receiving the degree of Ph.D. from that institution. For three years after his graduation he was assistant in the department of mineralogy at Columbia University, and from thence until 1900 he was on the staff of instructors of the department of metallurgy, first assisting Dr. Thomas Egleston, and later Prof. Henry M. Howe; later becoming honorary lecturer in metallurgy at Columbia University. In 1896 he organized and conducted the first summer school in practical metallurgy of Columbia University, which was held at Butte, Mont., and, in the following year, the summer schools at Chicago and Pittsburg were under his charge. In 1898 and 1899 he assisted at the summer schools held in Pennsylvania and Maryland. Dr. Struthers has visited many metallurgical plants in the United States and Europe, and he has carried on special investigations in calorimetry, measurement of furnace temperatures, microscopical examination of metals and slags, and work of like character. He has written numerous articles for the *Engineering and Mining Journal* and the *School of Mines Quarterly*, and from 1892 to the present time he has been on the Board of Editors of the latter publication, acting for most of this period as business manager. As assistant editor of THE MINERAL INDUSTRY, Vols. VIII. and IX. and Editor of Vol. X. he has had entire charge of their preparation, and has contributed to them by far the greater number of the unsigned articles. In November, 1901, Dr. Struthers was appointed Field Assistant to the United States Geological Survey, and he has contributed many articles on the minor metals and minerals for the forthcoming volume of *The Mineral Resources.*

TUCKER, SAMUEL AUCHMUTY, was graduated in 1895 from Columbia School of Mines in the course of chemistry, and became assistant in physiological chemistry, College of Physicians and Surgeons in 1895; assistant in toxicology, 1896; assistant demonstrator in chemistry and physics, 1896; and tutor in industrial chemistry at School of Applied Science, Columbia University, in 1897. Mr. Tucker is a member of several chemical societies and has contributed the results of his research work with the electric furnace at high temperatures to various chemical publications. To the present volume he contributes the paper, "Manufacture of Potassium Cyanide."

ULKE, TITUS, was born in 1866, at Washington, D. C. In 1889 he was graduated from the Royal School of Mines at Freiberg, Saxony, as metallurgical engineer. After spending some time in visiting the various mines and metallurgical works in Europe, Mr. Ulke returned to this country and was engaged as chemist to the Harney Peak Tin Co., in South Dakota. In 1891 he became assayer for the United Smelting Co., and afterwards was

engaged by the Anaconda Mining Co., as chemist at its electrolytic copper refining works. In 1893 Mr. Ulke acted as metallurgist to the Mines and Mining Department of the Chicago Columbian Fair, and was later employed at the Guggenheim works at Perth Amboy, N. J. As triangulator for the U. S. Geological Survey in 1897, he had charge of a party to survey the Montana timber reserves. Soon after the declaration of war with Spain, Mr. Ulke was appointed Assistant Inspector of Ordnance, U. S. A., which position he resigned in 1900 to become metallurgical engineer to the Lake Superior Power Co., Sault Ste. Marie, Ont. Mr. Ulke has contributed to the present volume the papers, "Progress in the Electrolytic Refining of Copper in 1901," and "Progress in the Metallurgy of Nickel."

WATSON, JOHN R., was educated at Bolton High School, Lancashire, at Manchester Technical School and at Normal School of Science, London. For nine years he was employed by Brunner Mond & Co., in England, as engineer, and in 1893-94 he remodeled the plant of the Fords Alkali Co., the bicarbonate plant at Natrona, Pa., and the Diamond soda plant at Milwaukee, Wis. Mr. Watson at present is employed as engineer for the Lake Superior Power Co., and has made a special study of the design of chemical machinery, used in the heavy chemical industry, Mond gas producers, Semet-Solvay coke ovens, ammonia plants and sulphite-pulp machinery. To the present volume Mr. Watson contributes the illustrated article, "An Improved Ammonium Chloride Distiller for a 100-Ton Soda Ash Plant."

WEED, WALTER HARVEY, was born in St. Louis, Mo., May 1, 1862, and was graduated in 1883 from Columbia College School of Mines in the course of mining engineering. Mr. Weed was appointed assistant geologist U. S. Geological Survey in June, 1883; in 1885 discovered the vegetable origin of the siliceous sinter of Yellowstone; and the following year discovered and described Death Gulch, Yellowstone Park. Following his specialty of economic and applied geology, Mr. Weed has investigated and reported on various coal, gold and silver districts of Montana, and has made careful studies of the copper and gold regions of Virginia and the Carolinas, Cripple Creek district, and others in Colorado, Arizona, California, Wyoming and Mexico. To the present volume Mr. Weed contributes the monograph, "Montana Sapphires" and the reviews of progress of copper mining in North Carolina and Virginia.

WELLS, JAMES S. C., was graduated from Columbia College (now Columbia University) School of Mines, in 1875, in the chemistry course, and later was given the degree of Ph.D. by that institution. From 1875 to 1879 he was assistant in quantitative analysis, and from 1879 to the present time he has filled the position of instructor in analytical chemistry at Columbia University. During this time he has also engaged in other professional work as a chemist, metallurgist, and mine examiner. Dr. Wells has written numerous articles for scientific journals, and for this volume he has contributed the "Review of Progress in the Cyanide Process during 1901."

WILKENS, H. A. J., was graduated in 1887 as a mining engineer from Lehigh University, Bethlehem, Pa., and during 1889 studied at the Royal School of Mines, at Freiberg, Saxony. His first professional work was performed for the Lehigh Zinc & Iron Co., at South Bethlehem, Pa., later for the Empire Zinc Co., at Joplin, Mo. During the year 1890 Mr. Wilkens was in charge of the operations of the Gold King Mining Co., of San Diego County, Cal., and from 1891 to 1895 acted as mining engineer in charge of the Franklin Lehigh Zinc & Iron Co., at Franklin Furnace, N. J. In 1895 he became general manager of the Wetherill Concentrating Co., continuing in this capacity until the company's patents were sold in 1897. At present Mr. Wilkens is consulting engineer for the Wetherill Separating Co., and manager of the acid and mining departments of the New Jersey Zinc Co. He contributes to the present volume the monograph, "Recent Progress in the Wetherill System of Magnetic Concentration."

INTRODUCTION.

THE total value at the place of production of the mineral and metal output from both domestic and foreign ores and bullion of the United States in 1901 was $1,372,826,102, as compared with $1,369,256,563 in 1900, a gain of $3,569,539 for the year.

Of these vast sums, which are without precedent in the history of the mineral industry, ores and minerals contributed $723,348,715 in 1901 and $672,090,416 in 1900; metals, $490,279,923 in 1901 and $524,432,533 in 1900; secondary products, $73,068,974 in 1901 and $76,372,375 in 1900; while the value of metals smelted or refined from foreign material was $86,128,490 in 1901 and $96,364,939 in 1900. In these gross totals of value are included certain duplications, such as those of the manganese and iron ore used in making ferromanganese and pig iron; bauxite used in making aluminum and alum; coal used in making coke; lead used in making white and red lead and litharge and a few other duplications, the whole amounting in 1901 to $93,629,061 and in 1900 to $116,768,662. Deducting these amounts and also the values of the crude foreign ores or metals smelted or refined here, the net value of the mineral industry of the United States was $1,193,068,461 in 1901, and $1,156,126,662 in 1900.

In the preparation of the statistics for this volume, the figures previously reported for 1900 have been revised in the light of later and more minute investigation, in accordance with our practice, wherefore it is important for students to observe the caution to use always the figures in the latest volume of THE MINERAL INDUSTRY. There are no statistical reports of this nature which are absolutely correct, owing to the practical impossibility of obtaining accurate reports from all the producers in some extensive and greatly subdivided industries, the absence of records on the part of many producers which prevents them from making returns, the unwillingness of a few to give their figures, and confusion as to the stage in which many products are to be reported. The last difficulty is especially likely to lead to errors in values, some producers estimating the worth of their product at the pit's mouth, and others reporting it in a more or less advanced state of completion, including thus not only the cost of carriage, but also the cost of manipulation. These difficulties appear not only in our own statistics, but also in the statistics reported by various governments. In our own work, however, we make a practice of going backward and correcting figures previously reported, whenever mistakes are discovered by subsequent investigation.

For the greater part of the statistics relating to the domestic production of the United States during 1901 we have been indebted to Department of Mineral Resources of the United States Geological Survey, and for the production of gold and silver in the United States during 1901 to Mr. George E. Roberts, Director of the Mint. Special acknowledgment is due to both of these departments for their active and hearty co-operation.

We have made great use of the reports of several State geological surveys,

especially those of Alabama, Kansas, Iowa and Montana, and the State mining bureaus of California and Colorado. We have generally credited these figures to the proper sources in the subsequent pages, but this acknowledgment may stand for any unintentional oversights.

PRODUCTION OF ORES AND MINERALS IN THE UNITED STATES. (FIRST PRODUCTS.)

Number.	Products.	Customary Measures.	1900. Quantity. Customary Measures.	1900. Quantity. Metric Tons.	1900. Value at Place of Production. a Totals.	1900. Value at Place of Production. a Per M. Ton.	1901. Quantity. Customary Measures.	1901. Quantity. Metric Tons.	1901. Value at Place of Production. a Totals.	1901. Value at Place of Production. a Per M. Ton.
					$	$			$	$
1	Asbestos	Sh. T.	1,100	998	16,500	16·53	747	678	13,498	19·91
2	Asphaltum	Sh. T.	11,140	10,106	218,520	21·62	21,916	19,887	383,359	19·28
3	Asphaltic limestone	Sh. T.	3,910	3,547	16,830	4·74	6,970	6,325	33,375	5·28
4	Bitumin's sandstone	Sh. T.	34,277	31,096	138,892	4·47	34,248	31,078	138,601	4·46
5	Barytes	Sh. T.	41,466	37,618	161,717	4·30	49,070	44,528	157,844	3·54
6	Bauxite	L. T.	23,445	23,820	85,922	3·61	18,905	19,214	79,914	4·16
7	Bismuth ore	Sh. T.	221	200	26,500	132·50	319	289	25,488	88·19
8	Bromine	Lb.	521,444	236	140,790	596·57	552,023	250	149,045	596·18
9	Calcium borate. c	Sh. T.	25,350	22,997	532,350	23·15	23,231	21,075	1,012,118	48·02
10	Cement, nat. hydraul.	g Bbls	9,177,222	1,248,828	4,308,709	3·45	7,084,823	963,921	3,056,278	3·17
11	Cement, Portland	h Bbls	7,991,689	1,449,994	10,461,910	7·21	12,711,225	2,306,756	12,532,360	5·43
12	Chrome ore	L. T.	*Nil.*	*Nil.*	*Nil.*	*Nil.*	368	374	5,790	15·48
13	Clay products				78,704,678				110,211,587	
14	Coal, anthracite	Sh. T.	57,464,235	52,131,212	102,972,596	1·97	67,471,667	61,226,558	112,504,020	1·84
15	Coal, bituminous	Sh. T.	210,821,727	191,256,216	219,460,521	1·15	224,869,091	203,964,692	236,309,811	1·16
16	Coal, cannel	Sh. T.	20,471	26,736	88,413	3·31	(ff)			
17	Cobalt oxide	Lb.	12,270	k 5,566	22,085	k 3·97	13,360	k 6,062	24,048	k 3·97
18	Copper sulphate. f	Lb.	78,218,478	35,480	m 3,908,102	110·01	78,004,257	35,282	m 3,674,000	104·13
19	Corundum	Sh. T.	830	753	58,100	77·16	4,305	3,905	146,040	37·40
20	Emery	Sh. T.	4,200	3,810	189,000	49·06				
21	Feldspar	L. T.	29,447	29,918	136,773	4·57	31,019	31,517	220,422	6·99
22	Fluorspar	Sh. T.	21,656	19,646	114,430	5·82	19,586	17,773	113,803	6·40
23	Fullers earth	Sh. T.	11,813	10,717	70,565	6·58	10,967	9,949	80,697	8·11
24	Garnet	Sh. T.	3,285	2,980	92,801	31·14	4,444	4,033	158,100	39·20
25	Gilsonite	Sh. T.	3,279	2,975	98,370	33·07	1,500	1,653	46,000	27·82
26	Graphite, crystalline	Lb.	4,103,052	k 1,861,182	164,122	k 0·09	3,967,612	k 1,800,187	135,914	k 0·08
27	Graphite, amorphous	Sh. T.	1,045	948	8,640	9·11	809	734	31,800	43·32
28	Gypsum	Sh. T.	484,202	439,265	1,316,255	3·00	659,659	598,602	1,577,493	2·64
29	Iron ore	L. T.	25,917,393	26,332,071	77,752,179	2·95	28,887,479	29,359,325	49,256,945	1·60
30	Lepidolite	Sh. T.	100	91	3,700	40·66	e 110	100	4,070	40·66
31	Magnesite. c	Sh. T.	2,708	2,456	11,832	4·82	13,172	11,949	43,057	3·60
32	Manganese ore. i	L. T.	218,222	221,714	461,594	2·08	638,705	649,016	1,644,117	2·53
33	Mica, scrap	Sh. T.	5,417	4,914	o 42,889	8·73	2,165	1,964	19,719	10·04
34	Mica, sheet	Lb.	127,241	k 57,716	82,5 8	k 1·43	360,060	k 163,322	98,859	k 0·61
35	Molybdenum ore	Sh. T.	24	22	1,200	54·55	15	15	750	5·14
36	Monazite	Lb.	908,000	412	50,680	123·01	748,736	340	59,262	174·30
37	Natural gas				e 18,500,000				27,067,500	
38	Ocher. p	Sh. T.	41,917	n 38,027	461,087	12·13	43,036	n 39,042	516,306	13·48
39	Petroleum, crude	g Bbls	63,538,544	8,749,458	74,246,582	8·48	69,389,194	8,839,263	66,417,335	7·51
40	Phosphate rock	L. T.	1,527,711	1,552,154	5,375,956	3·46	1,480,358	1,504,538	5,354,022	3·56
41	Precious stones				200,000				289,050	
42	Pyrites	L. T.	201,317	204,536	684,478	3·35	284,825	288,661	1,024,449	4·29
43	Salt. q	Bbls	20,738,729	2,633,967	6,439,006	2·44	20,566,661	2,613,299	6,617,4 9	2·53
44	Silica, brick	M.	49,531		916,819		55,000		1,018,050	
45	Diatom. earth	Sh. T.	1,375	1,247	9,675	7·76	dd 4,020	3,647	52,950	14·52
46	Flint	Sh. T.	35,915	32,582	84,400	2·59	34,420	31,234	149,298	4·78
47	Sand, etc	L. T.	e 875,000	989,000	e 1,312,500	1·48	e 900,000	914,400	e 1,353,912	1·48
48	Pumice	Sh. T.	250	227	n 1,250	5·51	*Nil.*			
49	Grindstones	Sh. T.	42,039	38,138	482,402	12·65	bb 16,807	15,247	165,665	10·86
50	Whetstones				84,874				158,300	
51	Tripoli	Sh. T.	1,846	1,675	3,987	2·38	(ee)			
52	Slate, roofing	Sq'es.	990,036	299,385	2,885,158	j 2·91	1,304,379	394,072	4,114,410	j 3·15
53	Manufactures				502,051				673,115	
54	Pigment	Sh. T.	6,617	6,003	72,787	12·13	4,865	4,413	41,211	9·34
55	Soapstone	Sh. T.	18,956	17,197	189,560	11·02	(cc)			
56	Soda, natural. r	Sh. T.	14,100	12,791	195,900	15·27	15,000	13,608	197,000	14·48
57	Stone, for building				e 41,400,000				55,615,926	
58	Stone, limestone (flux)	L. T.	6,790,200	6,898,843	3,666,708	0·53	8,540,168	8,679,656	4,659,886	0·54
59	Stone, lithographic	Sh. T.	40	36	n 2,000	55·56	*Nil.*			
60	Sulphur	L. T.	4,630	4,704	m 102,001	21·70	7,690	6,978	m 223,430	32·02
61	Sulphuric acid. f. l	Sh. T.	85,000	77,111	m 2,045,950	26·53	98,000	88,905	m 2,203,200	25·75
62	Talc, common	Sh. T.	7,770	7,049	60,217	8·54	dd 28,643	25,984	424,888	16·35
63	Talc, fibrous	Sh. T.	45,000	40,824	236,250	5·79	69,200	62,778	488,600	7·69
64	Tungsten ore	L. T.	220	224	35,200	157·14	160	162	27,720	171·11
65	Uranium ore	Sh. T.	153	139	e 45,900	330·22	375	340	102,500	301·47
66	Zinc sulphate	Sh. T.	527	478	22,657	47·40	7,500	6,804	332,425	47·39
67	Zinc ore, exported	Sh. T.	42,092	38,156	1,133,663	30·00	44,156	40,058	t 167,684	29·15
68	Zinc white. s	Sh. T.	47,151	42,775	3 772,080	88·18	46,500	42,185	3,720,000	88·18
69	Zinc-lead	Sh. T.					2,500	2,268	150,000	66·14
70	Est. prod. unspecified				5,000,000				5,000,000	
	Totals				672,090,416				723,348,715	

PRODUCTION OF METALS IN THE UNITED STATES.

Number.	Products.	Customary Measures.	1900. Quantity. Customary Measures.	1900. Quantity. Metric Tons.	1900. Value at Place of Production. Totals.	1900. Value at Place of Production. Per M. Ton.	1901. Quantity. Customary Measures.	1901. Quantity. Metric Tons.	1901. Value at Place of Production. Totals.	1901. Value at Place of Production. Per M. Ton.
					$	$			$	$
71	Aluminum	Lb.	7,150,000	*k* 3,243,219	*m* 2,288,000	*k* 0·71	7,150,000	*k* 3,243,219	2,288,000	*k* 0·69
72	Antimony	Lb.	3,200,000	1,452	301,440	207·60	5,298,000	2,404	542,020	225·47
73	Copper	Lb.	600,882,505	272,596	97,755,449	*t* 358·69	597,443,212	270,998	86,629,266	319·67
74	Ferromanganeseu	L. T.	255,977	260,073	22,825,469	87·77	291,461	295,124	16,589,960	56·21
75	Ferromolybden'm	Lb.	11,000	5	12,100	2,420·00	16,000	7	19,600	2,800·00
76	Ferrotungsten	Lb.	.....	.....	.....	.....	13,000	6	3,770	628·34
77	Gold	Oz(*w*)	3,781,310	*k* 117,611	78,159,674	*k* 664·60	3,880,578	*k* 120,699	80,218,800	*k* 664·60
78	Iron, pig	L. T.	13,583,265	13,749,797	250,184,857	18·49	15,586,893	15,836,283	232,800,328	14·70
79	Iridium	Oz(*w*)	8	.....	311	.....	253	.....	5,060	29·00
80	Lead	Sh. T.	275,907	250,301	24,114,272	96·34	270,700	245,644	23,280,200	94·77
81	Molybdenum	Lb.	32,000	*k* 14,515	46,080	*k* 3·17	35,000	16	62,125	3,882·81
82	Nickel	Lb.	9,715	*k* 4,407	*m* 4,534	*k* 1·02	6,700	3,040	3,551	*k* 1·17
83	Platinum	Oz(*w*)	173	*k* 5·4	3,114	*k* 576·67	1,408	*k* 44	27,526	625·59
84	Quicksilver (*x*)	Fl'sks	27,855	967	1,288,851	1,332·84	29,727	1,031	1,382,305	1,340·74
85	Silver	Oz(*w*)	59,561,797	*k* 1,852,564	36,576,900	*k* 19·74	59,653,788	*k* 1,855,425	35,165,902	*k* 18·95
86	Tungsten	Lb.	57,000	25,855	51,300	2·00	75,000	34	45,750	1,345·59
87	Zinc	Sh. T.	123,231	111,794	10,819,682	96·78	140,822	127,788	11,965,760	88·16
	Totals	.....	.....	.....	$524,432,533	.....	.....	.....	$490,279,923	.....

SECONDARY MINERAL AND CHEMICAL PRODUCTS OF THE UNITED STATES.

Number.	Products.	Customary Measures.	1900. Quantity. Customary Measures.	1900. Quantity. Metric Tons.	1900. Value at Place of Production. *a* Totals.	1900. Value at Place of Production. *a* Per M. Ton.	1901. Quantity. Customary Measures.	1901. Quantity. Metric Tons.	1901. Value at Place of Production. *a* Totals.	1901. Value at Place of Production. *a* Per M. Ton.
					$	$			$	$
88	Alum	Sh. T.	20,531	18,626	615,930	33·07	7,755	7,036	208,846	29·68
89	Aluminum sulphate	Sh. T.	61,678	55,954	1,480,272	26·45	74,721	67,786	1,355,720	20·00
90	Ammonium sulphate	Sh. T.	63,333	58,000	3,651,680	62·96	66,138	60,000	3,665,400	61·09
91	Carborundum	Lb.	2,401,000	1,089	216,090	198·43	3,838,175	1,741	345,435	198·41
92	Cement, slag	*h* Bbls	490,150	88,932	622,490	7·00	272,689	49,490	346,430	7·00
93	Coke	Sh. T.	19,206,994	17,424,471	50,272,050	2·89	21,789,945	19,773,090	44,431,522	2·25
94	Copperas	Sh. T.	12,374	11,226	96,517	8·59	23,586	21,397	112,366	5·25
95	Crushed steel	Sh. T.	345	313	48,300	154·23	345	313	37,950	121·25
96	Graphite, artificial	Lb.	860,750	*k* 390,434	68,860	*k* 0·18	2,500,000	*k* 1,134,301	119,000	*k* 0·10
97	Lead, white	Sh. T.	96,408	87,468	9,910,742	113·31	100,787	91,433	11,252,653	123·07
98	Lead, red	Sh. T.	10,098	9,161	1,050,192	114·64	13,103	11,897	1,448,550	121·95
99	Lead, orange miner'l	Sh. T.	825	748	100,650	134·56	1,087	986	224,667	227·86
100	Litharge	Sh. T.	10,462	9,491	1,067,124	112·44	9,460	8,582	979,586	114·14
101	Mineral wool	Sh. T.	6,002	5,445	60,320	11·08	6,272	5,690	68,982	12·15
102	Soda, manufactured	M. T.	.....	390,000	7,000,500	17·95	.....	480,000	8,318,400	17·33
103	Venetian red	Sh. T.	6,352	5,762	110,658	19·21	9,201	8,347	153,467	18·39
	Totals	.....	.....	.....	$76,372,375	.....	.....	.....	$73,068,974	.....

METALS PRODUCED FROM FOREIGN ORES AND BULLION. (*aa*)

Metals.	Customary Measures.	1900. Quantities. Customary Measures.	1900. Quantities. Kg.	1900. Values.	1901. Quantities. Customary Measures.	1901. Quantities. Kg.	1901. Values.
				$			$
Copper	Pounds	62,484,290	28,342,688	10,166,194	102,645,963	46,560,209	16,536,265
Gold	Troy oz.	1,948,519	60,605	40,275,883	1,730,856	53,835	35,776,794
Lead	Short tons	108,341	98,750,340	9,032,003	22,260	20,194,272	1,927,716
Nickel	Pounds	7,713,120	3,498,648	3,599,713	8,664,614	3,930,198	4,097,710
Silver	Troy oz.	46,619,726	1,450,024	33,291,146	45,410,085	1,412,404	27,850,005
Total values				96,364,939			$86,128,490
Total ores and minerals				672,086,716			723,348,715
Total metals				524,432,533			490,279,923
Total secondary products				76,372,375			73,068,974
Grand total, values				$1,369,256,563			$1,372,826,102

In using the statistics in the foregoing tables reference should also be made to the detailed tables under the respective captions further on in this volume, where many explanatory notes as to the statistics will be found. The following notes refer to the four preceding tables: (*a*) Except where otherwise specified. (*b*) Not enumerated. (*c*) Crude mineral. Nominal value for 1900. In 1901 includes 5,344 short tons of refined borax, valued at $697,807. (*d*) Partly estimated. (*e*) Estimated. (*f*) Includes by-product production. (*g*) Barrels of 300 lb. (*h*) Barrels of 400 lb. (*i*) Includes manganiferous iron ore; this is not duplicated in the

report of iron ore. (*j*) Value per square, *i.e.*, 100 sq. ft., lapped and laid; the weights are calculated on the basis 8 squares = 2,000 lb., but these figures are only approximately correct. (*k*) Kilograms or per kilogram. (*l*) Reduced to a basis of 66° B. (*m*) Average market price at New York. (*n*) Nominal. (*o*) Value before grinding. (*p*) Includes ocher, umber, sienna, and oxide of iron. (*q*) Includes salt used for the manufacture of alkali; the barrel of salt weighs 280 lb. (*r*) Reduced to a basis of 58% ash. (*s*) Includes a small amount made from spelter. (*t*) Average value of Lake copper at New York, less 0·25c. per lb. (*u*) Includes spiegeleisen, though the total value is reckoned as if the whole product were ferromanganese. (*v*) Average market price at Pittsburg. (*w*) Troy oz. (*x*) Flasks of 76·5 lb. (*y*) Barrels of 42 gal. (*z*) Includes a comparatively small amount made directly from ores. (*aa*) Not included in the preceding tables. (*bb*) Does not include 40,980 pieces of unspecified weight; the value, however, is included in the total. (*cc*) Included with common talc. (*dd*) Includes tripoli. (*ee*) Included with diatomaceous earth. (*ff*) Included with bituminous.

Abbreviations: Sh. T., short tons (2,000 lb.); L. T., long tons (2,240 lb.); M. T., metric tons (2,204·6 lb.).

METALS AND ALLOYS.

Aluminum.—The production of aluminum in the United States in 1901 was 7,150,000 lb. ($2,238,000), as compared with 7,150,000 lb. ($2,288,000) in 1900.

Antimony.—The production of antimony in the United States in 1901 was 5,298,000 lb. ($542,000), as compared with 3,200,000 lb. ($301,440) in 1900.

Copper.—The production decreased from 600,832,505 lb. ($97,755,449) to 597,443,212 lb. ($86,629,266) in 1901. The main increases were in Utah, California, Arizona and Lake Superior. Montana fell off considerably. In addition to the domestic copper produced in 1901, there were 102,645,963 lb. ($16,536,265) derived from foreign sources.

Ferromanganese.—The production of ferromanganese, including spiegeleisen, was 291,461 long tons ($16,589,960), as compared with 255,977 long tons ($22,825,469) in 1900.

Ferromolybdenum.—The production in 1901 was 16,000 lb. ($19,600), as compared with 11,000 lb. ($12,100) in 1900.

Gold and Silver.—The domestic production of gold in 1901 was 3,880,578 troy oz. ($80,218,800), as compared with 3,781,310 troy oz. (78,159,674) in 1900. The production of silver was 59,653,788 troy oz. ($35,165,902), as compared with 59,561,797 troy oz. ($36,576,900). Colorado's production of gold increased, principally due to Cripple Creek. South Dakota, California and Alaska, including Cape Nome and the American Yukon, also contributed to the increased production. Besides the production reported, 1,730,856 oz. of gold and 45,410,085 oz. of silver were smelted in the United States from imported ores. The average value of silver in the United States in 1901 was 58·95c. per oz., against 61·33c. per oz. in 1900.

Iron.—The production of pig iron in 1901, exclusive of ferromanganese and spiegeleisen, was 15,586,893 long tons ($232,800,328), as compared with 13,533,265 long tons ($250,184,857) in 1900. Of the production in 1901 9,546,793 long tons were Bessemer pig, against 7,943,452 long tons in 1900. Basic pig increased from 1,072,376 to 1,448,850 long tons. The remainder of the output is classed as foundry and forge iron.

Lead.—The domestic production in 1901 was 270,700 short tons ($23,280,200), against 275,907 short tons ($24,114,272) in 1900. The decrease was due largely to the restriction of output by the Idaho mines. The average price of lead at New York in 1901 was 4·334c., against 4·37c. per lb. in 1900. Besides the above, the American smelters in 1901 recovered 22,260 tons of lead from foreign ore and base bullion, against 103,341 tons in 1900.

Molybdenum.—Some 35,000 lb. of molybdenum ($62,125) were produced in 1901, as compared with 32,000 lb. ($46,080) in 1900. A considerable portion of the ore came from Arizona.

Nickel.—The domestic production of nickel was 6,700 lb. ($3,551), as compared with 9,715 lb. ($4,534) in 1900.

Platinum.—There was a production of 1,408 troy oz. ($27,526) of platinum from domestic ores in 1901, as compared with 173 oz. ($3,114) in 1900. The value of bar platinum at New York in 1901 averaged $19·55 per oz.

Quicksilver.—The production of quicksilver increased from 27,855 flasks ($1,288,851) to 29,727 flasks ($1,382,305) in 1901. Texas contributed 400 flasks to the total and Oregon 75 flasks.

Tungsten.—The production was 75,000 lb. ($45,750) in 1901, against 57,000 lb. ($51,800) in 1900.. The production of ferrotungsten in 1901 was 13,000 lb. ($3,770).

Zinc.—The production in 1901 was 140,822 short tons ($11,265,760), as compared with 123,231 short tons ($10,819,682) in 1900. Missouri and Kansas increased their production. The average price of spelter in New York in 1901 decreased to 4·08c. per lb., against 4·39c. per lb. in 1900.

Ores, Minerals and Chemical Products.

Alum and Aluminum Sulphate.—The production of crystallized alum in the United States in 1901 was 7,755 short tons ($208,846), as compared with 20,531 short tons ($615,930) in 1900. The production of aluminum sulphate in 1901 was 74,721 short tons ($1,355,720), as compared with 61,678 short tons ($1,480,272) in 1900.

Ammonium Sulphate.—The amount of ammonium sulphate recovered in the United States in 1901 was 60,000 metric tons ($3,665,400) as compared with 58,000 metric tons ($3,651,680) in 1900. The value of sulphate, basis 25%, was $61·09 per metric ton at New York in 1901, against $62·96 in 1900.

Asbestos.—The domestic production was 747 short tons ($13,498) in 1901, as compared with 1,100 short tons ($16,500) in 1900. In each year the production was made almost entirely by one mine in Georgia.

Asphaltum and Asphaltum Products.—The production of asphaltum, liquid and solid, in 1901 was 21,916 short tons ($383,359), as compared with 11,140 short tons ($218,520) in 1900, the output coming from California and Indian Territory. California and Kentucky, chiefly the former, produced 34,248 short tons ($138,601) of bituminous rock in 1901, as compared with 34,277 short tons ($138,892) in 1900. Utah and the Indian Territory produced 6,970 short tons ($33,375) of asphaltic limestone, as compared with 3,910 short tons ($16,830) in 1900. The output of Utah increased in 1901, while that of the Indian Territory showed a small decrease. The production of grahamite or gilsonite in 1901 was 1,500 short tons, as compared with 3,279 short tons in 1900.

Barytes.—The production in 1901 was 49,070 short tons ($157,844), as compared with 41,466 short tons ($161,717) in 1900. Of the production in 1900 Missouri furnished the larger output, the remainder being obtained in Virginia, Tennessee, North Carolina and Georgia.

Bauxite.—The production in 1901 was 18,905 long tons ($79,914), as compared with 23,445 long tons ($85,922) in 1900.

Bromine.—The production in 1901 was 552,023 lb. ($149,045), against

521,444 lb. ($140,790) in 1900. These figures include the bromine equivalent of potassium bromide which is produced in Michigan.

Calcium Borate.—The production in 1901 was 23,231 short tons, as compared with 25,350 short tons in 1900. Most of this product is colemanite, mined in California. The year 1901 was notable for the greatly increased prices per short ton, which were $43·57, as compared with $21 in 1900.

Carborundum.—The production reported by the sole producer was 3,838,175 lb. ($345,435) in 1901, as compared with 2,401,000 lb. ($216,090) in 1900.

Cement.—The total production of Portland cement in 1901 was 12,711,225 bbl. of 400 lb., valued at $12,532,360, as compared with 7,991,639 bbl. ($10,461,910) in 1900. The Lehigh district of Pennsylvania and New Jersey has maintained its supremacy as a center of production, and Michigan, and other States also showed important gains. Aside from the remarkable increase in production, the year 1901 was notable for the very low prices commanded by cement in the Eastern markets. The production of natural rock cement in 1901 was 7,084,823 bbl. of 300 lb., valued at $3,056,278, as compared with 9,177,222 bbl. ($4,308,709) in 1900. The Kentucky-Indiana district increased its output, but other parts of the United States showed a falling off owing to the competition with Portland cement. The production of slag cement in 1901 was 272,689 bbl. of 400 lb., valued at $346,430, against 490,150 bbl. ($216,090) in 1900.

Chrome Ore.—The production in 1901 was 368 long tons ($5,790), with no production for 1900. The entire production during 1901 was mined in California.

Clay.—The value of brick and other clay products made in the United States in 1901 was $110,211,587, as compared with $78,704,678 in the previous year.

Coal and Coke.—The total production of coal in the United States in 1901 was 292,340,758 short tons ($348,813,831), as compared with 268,315,433 short tons ($322,521,530) in 1900. The production of anthracite, all of it from Pennsylvania with the exception of an insignificant amount from Colorado, was 67,471,667 short tons ($112,504,020) in 1901, as compared with 57,464,235 short tons ($102,972,596) in 1900. Kentucky's production of cannel coal in 1901 is included under bituminous; the production in 1900 was 29,471 short tons ($88,413). The output of bituminous coal, of which Pennsylvania and the Central States are the largest producers, was 224,869,091 short tons ($236,309,811) in 1901, as compared with 210,821,727 ($219,460,521) in 1900. There was an increase in the output of all of the important coal-producing States in 1901. The total production of coke in 1901 was 21,789,945 short tons ($44,431,522), as compared with 19,206,994 short tons ($50,272,050) in 1900. Pennsylvania furnished about two-thirds of the output each year.

Cobalt Oxide.—The production of cobalt oxide in 1901 was 13,360 lb., as compared with 12,270 lb. in 1900.

Copperas.—The production in 1901 was 23,586 short tons ($112,366), as compared with 12,374 short tons ($96,517) in 1900. The chief producer in this country is the United States Steel Corporation, which controls all the wire and rod works recovering copperas as a by-product. The above statistics do not include

copperas converted into Venetian and Indian reds at the works of original production.

Copper Sulphate.—The production in 1901 was 78,004,257 lb., as compared with 78,218,478 lb. in 1900. Of this the amount recovered as a by-product, chiefly by gold and silver refiners, was 51,000,000 lb. in 1901 and 44,368,478 lb. in 1900. The remainder of the output each year was made from metallic copper previously reported in the production of that metal. The average value of copper sulphate at New York per 100 lb. was $4·71 in 1901, as compared with $4·99 in 1900.

Corundum and Emery.—The production of corundum and emery in 1901 was 4,305 short tons ($146,040), as compared with 830 short tons ($58,100) of corundum, and 4,200 short tons ($189,000) of emery in 1900. The production of steel emery or crushed steel in 1901 was 690,000 lb. ($37,950), against 690,000 lb. ($48,300) in 1900, the entire make each year being supplied by the Pittsburg Crushed Steel Co.

Feldspar.—The production in 1901 was 31,019 long tons ($220,422), as compared with 29,447 long tons ($136,773) in 1900. Pennsylvania, Massachusetts and New York being the chief producers each year.

Fluorspar.—The production in 1901 was 19,586 short tons ($113,803), as compared with 21,656 short tons ($114,430) in 1900, Illinois and Kentucky furnishing the entire output.

Fullers Earth.—The output in 1901 was 10,967 short tons ($80,697) as compared with 11,813 short tons ($70,565) in 1900.

Garnet.—The production in 1901 was 4,444 short tons ($158,100), as compared with 3,285 short tons ($92,801) in 1900, the output each year being furnished by New York, Pennsylvania and Connecticut. The domestic resources of this mineral are large, but the demand for it is limited.

Graphite.—The production of crystalline graphite in 1901 was 3,967,612 lb. ($135,914), as compared with 4,103,052 lb. ($164,122) in 1900. The production of amorphous graphite in 1901 was 809 short tons ($31,800), as compared with 1,045 short tons ($8,640) in 1900. The larger part of the crystalline product in 1900 was obtained from Ticonderoga, N. Y., but a considerable quantity was mined in Pennsylvania, where some of the old mines were reopened. One company produced 2,500,000 lb. ($119,000) of artificial graphite, as compared with 860,750 lb. ($68,860) in 1900.

Gypsum.—The production increased from 484,202 short tons in 1900 to 659,659 short tons in 1901. These figures represent the amount of crude rock quarried. The larger part of the production is marketed as stucco or plaster of Paris.

Iron Ore.—The production in 1901 was 28,887,479 long tons, as compared with 25,917,393 long tons in 1900, these figures being exclusive of the production of manganiferous iron ore, reported separately under manganese. The increase in the production was due chiefly to the Lake Superior ranges, the Southern States showing but a comparatively small gain.

Lead White, Red Lead and Litharge.—The production of white lead in 1901 was 100,787 short tons ($11,252,653), as compared with 96,408 short tons ($9,910,742) in 1900; of red lead, 13,103 ($1,448,550), as compared with 10,098

($1,050,192); of litharge, 9,460 ($979,586), as compared with 10,462 ($1,067,124) of orange mineral, 1,087 ($224,667), as compared with 825 ($100,650) in 1900. The larger part of these products is obtained by the corrosion of pig lead, but a small part of the white lead product is made directly from ores.

Limestone for Iron Flux.—Iron smelters consumed 8,540,168 long tons in 1901, as compared with 6,790,200 long tons in 1900, the increase being caused by the greater production of pig iron.

Lithographic Stone.—Utah produced 40 short tons in 1900, a like amount in 1899. There was no output reported during 1901.

Magnesite.—In 1901 California produced 13,172 short tons ($43,057), as compared with 2,708 short tons ($11,832) in 1900.

Manganese Ore.—The production of manganese ore, including manganiferous iron ore, was 638,795 long tons, as compared with 218,222 long tons in 1900.

Mica.—The production of sheet mica in 1901 was 360,060 lb. ($98,859), as compared with 127,241 lb. ($82,508) in 1900. The production of scrap mica was 2,165 short tons ($19,719) in 1901, as compared with 5,417 short tons ($42,889), the values of scrap mica being reckoned for the product before grinding. Practically the entire production of mica is made in South Dakota, New Hampshire, North Carolina and Nevada.

Mineral Wool.—The production in 1901 was 6,272 short tons ($68,992), as compared with 6,002 short tons ($60,320) in 1900. A part of this product was made from slag and a part by the fusion of natural rock, the latter being the more valuable.

Molybdenum Ore.—This ore was produced in the United States in 1901 to the amount of 15 short tons, valued nominally at $50 per ton, as compared with 24 short tons, valued at $50 per ton in 1900.

Monazite.—North Carolina produced 748,736 lb. ($59,262) in 1901, as compared with 908,000 lb. ($50,680) in 1900.

Natural Gas.—The production of natural gas in 1901 is estimated at a value of $27,067,500, as compared with $18,500,000 in 1900.

Ocher and Oxide of Iron Pigments.—The production of ocher, amber, sienna and natural oxide of iron ground pigment, the last being known commonly as "metallic paint," was 43,036 short tons ($516,306) in 1901, as compared with 41,917 short tons ($461,087) in 1900. The values are reckoned nominally at $11 per ton each year. These products merge into one another so that no satisfactory division of the statistics is possible. Pennsylvania is the largest producer.

Petroleum.—The total output in 1901 was 69,389,194 bbl. ($66,417,335), as compared with 62,538,544 bbl. ($74,246,582) in 1900. The increase was due to California, Texas and Colorado. The above values are calculated for crude oil at the wells. The average value was considerably lower in 1901 than in the previous year.

Phosphate Rock.—The production in 1901 was 1,480,358 long tons ($5,354,022), as compared with 1,527,711 long tons ($5,375,956) in 1900. The decrease in 1901 was due to a falling off in the export demand.

Salt.—The domestic output of salt decreased from 20,738,729 bbl, in 1900, to 20,566,661 bbl. in 1901.

Silica.—The production of vein and dike quartz in 1901 was 34,420 short tons ($149,298) as compared with 35,915 tons ($84,400) in 1900. The uses were chiefly in pottery, for packing acid towers, and for grinding for various purposes. The production of grindstones, which are made out of quartzite, or a very hard sandstone, in 1901, amounted to 16,807 short tons ($165,665) as compared with 42,039 tons ($482,462) in 1900. The weight of this production of 1901 does not include 40,980 pieces weight not specified but included in the value. The production of oilstones, scythestones and whetstones in 1901 was valued at $158,300, as compared with $84,874 in 1900. There was no production of pumice in 1901. The production of diatomaceous earth in the United States in 1901, including tripoli, was 4,020 short tons ($52,950), as compared with 1,375 short tons ($9,675) of diatomaceous earth and 1,846 short tons ($3,987) of tripoli in 1900.

Slate.—The production of roofing slate in 1901 was 1,304,379 squares ($4,114,410) as compared with 990,036 squares ($2,885,153) in 1900. The production of slate manufactures, chiefly blackboards and structural material, was valued at $673,115 in 1901, as against $502,051 in 1900. The production of slate pigment, including Baraga graphite and various kinds of mineral black, was 4,865 short tons, as against 6,617 short tons in the previous year, the values of the products after grinding being respectively $41,211 and $72,787.

Soda.—The production of soda and soda products from salt, reduced to a common basis of 58% soda ash, was 480,000 metric tons in 1901, as compared with 390,000 metric tons in 1900. The average value of 58% ash at the works was $17·33 per metric ton, as compared with $17·95 in 1900. California and Nevada produced 15,000 short tons ($197,000) of natural soda, basis 58%, in 1901, as compared with 14,100 short tons (5195,300) in 1900.

Sulphur and Pyrites.—Louisiana, Nevada and Utah produced 7,690 long tons of sulphur in 1901, against 4,630 long tons in 1900. The average price of Sicilian seconds at New York in 1901 was $22·94 per ton, compared with $22·18 in the previous year. The domestic production of pyrites in 1901 was 234,825 long tons ($1,024,449), as against 201,317 long tons ($684,478) in 1900. Virginia was the largest producer each year, Massachusetts ranking second. Sulphuric acid was recovered as a by-product in roasting blende and pyrites, chiefly the former, to the extent of 98,000 short tons, as against 85,000 tons in 1900, the figures being reduced to a common basis of 66°B. Concentrated acid of the latter strength averaged $23·40 per 2,000 lb. at New York in 1901, as against $24·07 in 1900.

Talc and Soapstone.—The production during 1901 of soapstone for slabs and other manufactured articles and common talc, mostly ground to powder was 28,643 short tons ($424,888), as compared with 18,956 short tons ($189,560) of soapstone and 7,770 short tons ($60,217) of common talc during 1900. This was produced chiefly in North Carolina, New Jersey and Vermont. The production of fibrous talc, nearly all of it from St. Lawrence County, N. Y., was 69,200 short tons ($483,600), as compared with 45,000 short tons ($236,250) in 1900.

Tungsten Ore.—There was a production in 1901 of 160 long tons of tungsten ore from South Dakota, Colorado and Arizona, with a small amount from Connecticut and New Mexico, which was valued nominally at $27,720 at the mines. The statistics for 1900 were 220 long tons, valued at $35,200.

Uranium Ore.—In 1901 Colorado produced 375 short tons of uranium ore, estimated at a value of $102,500, as compared with 153 short tons, valued at $45,900 in 1900.

Venetian Red.—The production of Venetian and Indian reds in 1901 was 9,201 short tons ($153,467), as compared with 6,352 short tons ($110,658) in 1900. These figures include only the output at works where the original copperas was made, and do not include any that may have been made by second handlers.

Zinc Ore.—The amount of zinc ore of domestic origin exported from the United States in 1901 was 44,156 short tons ($1,167,684), as compared with 42,062 short tons ($1,133,663) in 1900. Most of the ore exported was mined in New Jersey, although a considerable portion was shipped from Colorado via New Orleans and Galveston.

Zinc Sulphate.—There was a production of zinc sulphate in 1901 of 7,500 short tons, as compared with 527 short tons in 1900.

Zinc White.—The production in 1901 was 46,500 short tons, as compared with 47,151 short tons in 1900. The total value was $3,720,000, as compared with $3,772,080 in 1900. Nearly all the American production of zinc white is made directly from the Franklinite ores mined in New Jersey.

ALUMINUM AND ALUM.

UNDER this general caption are grouped aluminum, alum, bauxite, cryolite, corundum and emery, substances which, previous to Volume VII., appeared under individual captions. The present arrangement is a logical one, since both bauxite and cryolite are used as raw material in the manufacture of aluminum and alum, two industries so interwoven that a logical separation is impossible, and, since corundum, though employed mainly as an abrasive, is now used in part as a source of aluminum. In this view aluminum, alum and the aluminum minerals—bauxite and cryolite, corundum and emery—bear the same relation to one another as do copper, copper sulphate or bluestone and copper ores.

I. BAUXITE.

The production of bauxite in 1901 was 18,905 long tons, valued at $79,914, being a large falling off from the output of the preceding year. Of the production in 1901, Georgia contributed the largest quantity, followed by Alabama and Arkansas, the last named State producing but 867 long tons. The following companies were in operation during the year: Republic Mining & Milling Co., in Alabama and Georgia; Southern Bauxite Mining & Milling Co., J. H. Hawkins, Harrison Bros., International Aluminum Mining Co., in Georgia; and Southern Bauxite Mining & Milling Co., Pittsburg Reduction Co., and one minor producer in Arkansas. The mines of the Illinois Chemical Co. were inoperative during the year.

Bauxite is consumed chiefly for the manufacture of aluminum, although a large quantity is used in the manufacture of aluminum sulphate and crystallized alum. In order to ascertain the annual consumption of bauxite and its value in the United States during the past five years the following table has been compiled which includes total production, imports, exports and consumption, with the respective values of each.

PRODUCTION, IMPORTS, EXPORTS, AND CONSUMPTION OF BAUXITE IN THE UNITED STATES.

Year.	Production.					Imports.		Exports.		Consumption.	
	Alabama.	Georgia.	Total. (a)								
	Lg. Tons.	Lg. Tons.	Lg. Tons.	Value.	Per Ton.	Lg. Tons.	Value.	Lg. Tons.	Value.	Lg. Tons.	Value.
1897..	13,083	7,507	20,590	$51,475	$2·50	2,645	$10,515	2,537	$5,074	20,708	$56,916
1898..	13,848	12,943	26,791	66,978	2·50	1,201	4,238	1,000	2,000	26,992	69,216
1899..	14,144	19,619	36,813	101,235	2·75	6,666	23,768	2,030	4,567	41,449	120,436
1900..	650	20,715	23,445	85,922	3·66	8,656	32,967	1,000	3,000	31,101	115,889
1901..	18,088		18,905	79,914	4·23	18,313	66,107	1,000	3,000	36,218	144,021

(a) Arkansas produced 3,050 long tons in 1899, 2,080 long tons in 1900, and 867 long tons in 1901, which are included in the totals for those years.

Alabama and Georgia.—(By Thomas L. Watson.)—The Southern Appalachian bauxite deposits are located in northwest Georgia and the adjacent portion of Alabama, and are limited to the central and southeastern portions of the Coosa valley, extending from Adairsville, Ga., southwestward to near Jacksonville, Ala., a distance of about 60 miles, occupying portions of Bartow, Floyd, Polk, Walker, Chattooga and Gordon counties, in Georgia, and of Cherokee, Cleburne and Calhoun counties in Alabama. The deposits are irregularly distributed over the area, and are grouped about certain centers or along certain lines of fracture forming four groups as follows: The Hermitage district, including portions of Bartow and Floyd counties; the Bobo district, including portions of Floyd and Polk counties; the Summerville district, including portions of Chattooga and Walker counties, in Georgia; and the Dykes' district in Cherokee County, Ala. Several single isolated deposits are found outside the limits of the districts in Georgia, but they have not as yet been worked.

The bauxite deposits are associated with the Knox dolomite, which is a gray crystalline magnesian limestone between 4,000 and 5,000 ft. in thickness and contains an abundance of chert in the form of lens and small nodules. It is part Cambrian and part Lower Silurian (Ordovician) in age. The bauxite occurs as distinct pocket deposits of variable size, the largest of which yield several hundred tons of the ore. They differ from the Arkansas and some foreign deposits in not being stratified; and from certain other accumulations of bauxite in not occurring as an alteration or residual product derived from the decay or other change of pre-existing rock. No rocks of igneous origin are found within the limits of the Georgia-Alabama bauxite area. The ore bodies are definitely connected with the numerous fault lines of the region, and as such the ore bodies are believed to have been formed about vents and springs supplied by the ascending currents of percolating water along the lines of breakage. The alumina has been derived from the great thickness of the immediately underlying middle Cambrian aluminous shales. On physiographic grounds, the age of the Southern Appalachian bauxite deposits is fixed near the close of the Eocene. In the early history of mining in this field, the output from Alabama greatly exceeded that from Georgia, and previous to the working of the Arkansas bauxite deposits in 1899, the entire production in America was from the Georgia-Alabama area. The greater part of the bauxite mined in Georgia and Alabama is used in the manufacture of alum, only a small percentage of the whole being utilized in the manufacture of the metal aluminum. The first grade ore brings $5·50 and the second grade $4·50 per long ton.

Arkansas.—The bauxite deposits are confined chiefly to two districts, one a small area south of Little Rock, about 20 miles long and 5 or 6 miles wide, lying in eastern Pulaski County and northern Saline County, the other and more important embracing about 12 square miles in Bryant township. Between these districts are several isolated deposits. In thickness the bauxite bed varies up to 40 ft., the average being between 10 and 15 ft. The greatest thickness—30 ft.—occurs in section 16. The best grade of bauxite produced is the granite variety containing less than 3% SiO_2 and very little iron except that which can be removed by hand washing.

The Pittsburg Reduction Co. is erecting an extensive mining plant at Bauxite, Saline County, which is expected to be in operation in the latter part of 1902. The production of bauxite from Arkansas will be greatly increased by the output from the new works.

California.—A large deposit of disintegrated rock containing free alumina, has been discovered in California,[1] containing from 31 to 35% Al_2O_3, together with FeO, MgO, and SiO_2. The ore is stated to be associated with quartz ledges assaying from $2 to $39 per ton in gold, and the two minerals may therefore be worked together. While the large beds of purer bauxite remain unexhausted in Florida, it is doubtful however whether the Californian deposits will be drawn upon, as they are situated 17 miles from the nearest point on the Southern Pacific Railroad. With regard to the methods of treating bauxite for extraction of the alumina in a form which can be used in the electrolytic baths, Hall has secured three American patents. The details of these patents are given elsewhere in this section under the caption *Production.* The new process may have a very important effect upon the future of aluminum, if, as the inventor evidently hopes, it can be carried out more cheaply than the present method of preparing the refined alumina. By the latter, the cost of the alumina represents 30% of the total cost of manufacturing aluminum of the higher grades. The following estimate of itemized cost per pound of aluminum produced, was published by the late Capt. Hunt some years ago, and is still fairly correct:—

Energy, 5c.; alumina, 6c.; electrodes, 2c.; chemicals and stores, 1c.; labor and superintendence, 3c.; interest and maintenance, 3c.; total cost, 20c.

A process which would cut down the cost of the refined alumina to 2c. per lb. would therefore make it possible for aluminum to be sold at 20 to 24c. per lb. and would have a notable effect in extending the utilization of the light metal, in the arts and industries.

Imports and Exports.—There was an unusually large importation of French bauxite during 1901, which amounted to 18,313 long tons valued at $66,107, as compared with 8,656 long tons valued at $32,967, in 1900. This increase was due mainly to the low ocean freight rate of an average of $2·25 per long ton from foreign ports, which, with the import duty of $1 per long ton, permitted the delivery from the south of France at New York, Philadelphia, and Baltimore at a lower rate per ton than it cost to ship by rail from Georgia or Alabama. The high iron content of the French bauxite prevents its use for the manufacture of aluminum sulphate, and it is consumed mainly in making aluminum hydrate, which is used as a raw material for the manufacture of aluminum. The exports of bauxite during 1901 were 1,000 long tons, valued at $3,000.

The world's supply of bauxite is derived chiefly from France, Ireland, and the United States, the production from 1894 to 1900, inclusive, being given in the subjoined table:—

[1] *Electricity* (New York), Sept. 18, 1901.

PRODUCTION OF BAUXITE IN THE PRINCIPAL COUNTRIES. (IN METRIC TONS.)

Country.	1894.	1895.	1896.	1897.	1898.	1899.	1900.
France	26,082	17,956	33,830	41,740	36,723	48,215	58,530
United Kingdom	8,097	10,574	7,365	13,449	12,600	8,137	5,871
United States	10,904	19,101	17,370	20,919	27,290	37,402	23,890
Total	45,083	47,633	58,555	76,108	76,543	93,754	88,291

Italy.—(By Giovanni Aichino.)—The recently discovered deposits of bauxite are situated in the central part of the Apennine Mountains, the most important being at Lecchi né Marsi, on the slopes of Monte Turchio; the nearest railway station is Pescina, on the Roma-Sulmona line. The deposit is at least 250 acres in extent, and averages from 3 to 10 ft. in thickness. The ore is brownish-red to reddish-white in color, and is more or less compact, sometimes being earthy.

The following analyses of bauxite have been reported from the laboratory of the Royal Board of Mines, Geological Survey. Specimens Nos. 1 to 5, inclusive, are from Lecchi né Marsi, and No. 6 from Petraroja. Analyses Nos. 1 to 4 were made by G. Aichino, and Nos. 5 and 6 by E. Mattirolo.

ANALYSES OF ITALIAN BAUXITE.

Components.	Ore from Lecchi né Marsi.					Ore from Petraroja.
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
	%	%	%	%	%	%
Al_2O_3	57·60	56·79	54·46	56·89	47·44	58·65
Fe_2O_3	26·55	26·20	30·63	25·98	36·37	18·62
SiO_2	2·79	2·98	2·48	4·06	2·38	7·91
TiO_2	1·27	2·21	1·17	1·28	2·86	
CaO	.....	.....	.....	.....	0·38	0·30
MgO	.....	.....	.....	.....	0·41	0·37
H_2O at 110° C.	(Specimens dried at 110° C.)				0·84	0·87
Loss by ignition	11·71	11·95	11·28	12·17	10·17	22·40
Total	99·92	100·13	100·12	100·38	100·70	99·82

New South Wales.—The following table, compiled from recent analyses, gives the composition of bauxite from various localities in New South Wales. The proportions of alumina and iron are very variable, and phosphoric acid and titanic acid are always present.

ANALYSES OF BAUXITE FROM NEW SOUTH WALES.

Locality.	Alumina.	Water.	Ferric Oxide.	Silica.	Lime.	Magnesia.	Soda and Potash.	Phosphoric Acid.	Titanic Acid.
	%	%	%	%	%	%	%	%	%
Five miles north of Inverell	31·43	20·38	27·06	15·01	.....	0·40	.....	0·34	4·98
Near Wingello...	58·31	32·68	2·85	1·80	.....	.....	.....	6·66	2·40
	35·28	17·81	12·90	29·80	.....	.....	.....	0·19	2·65
	39·82	22·30	20·34	10·30	.....	.....	.....	0·56	5·50
Emmaville:									
Red ore	42·20	23·45	28·91	0·16	0·28	0·37	0·17	0·26	4·75
Mottled ore	47·84	19·23	13·59	16·40	0·74	0·23	0·20	0·14	1·77
Yellow ore	28·96	15·51	16·20	35·56	0·50	0·31	0·20	0·05	2·98

Details of the progress in the purification of bauxite will be found under the caption "Aluminum," elsewhere in this section.

II. Corundum and Emery.

The production of corundum and emery and the imports of emery in recent years are given in the subjoined tables:—

PRODUCTION OF CORUNDUM AND EMERY IN THE UNITED STATES. (*a*)

Substance.	1898.			1899.			1900.			1901.		
	Tons. (*b*)	Value.	Per Ton.	Tons. (*b*)	Value.	Per Ton.	Tons. (*b*)	Value.	Per Ton.	Tons. (*b*)	Value.	Per Ton.
Corundum	788	$68,680	$80·96	970	$78,570	$81·00	880	$58,100	$70·00	4,305	$146,040	$37·40
Emery	2,956	c 143,800	48·65	3,000	150,000	50·00	4,200	189,000	45·00			
Steel emery	330	46,200	140·00	337	47,250	140·21	345	48,300	140·00	355	49,700	140·00
Total	4,073	$253,680	.....	4,237	$275,820	.....	5,375	$295,400	.....	4,660	$195,740	.....

(*a*) The values are based on the prices at the mines, but except in the case of steel emery are of slight significance owing to the great range between the different grades of the minerals. The changes in the annual averages do not indicate fluctuations in market quotations so much as changes in the proportion of different grades of mineral in the total. (*b*) 2,000 lb. (*c*) More or less nominal.

IMPORTS OF EMERY INTO THE UNITED STATES.

Year.	Grains.		Ore or Rock.		Other M'f'es.	Total Value.	Year.	Grains.		Ore or Rock.		Other M'f'es.	Total Value.
	Pounds	Value.	Long Tons.	Value.	Value.			Pounds.	Value	Long Tons.	Value.	Value.	
1894	597,713	$18,645	2,804	$51,487	$1,847	71,973	1898.	577,655	$23,820	5,547	$106,269	$3,810	$133,899
1895	678,761	25,066	6,803	80,386	27,586	133,038	1899.	728,299	29,124	7,435	116,493	11,514	157,131
1896	751,464	26,820	6,299	119,607	1,971	148,158	1900.	651,482	26,530	11,392	202,380	10,006	239,506
1897	530,095	20,022	5,209	107,649	2,211	129,882	1901.	1,716,729	43,207	12,441	240,856	10,927	294,990

Progress of the Corundum and Emery Industry during 1901.

By Joseph Hyde Pratt.

Two noteworthy changes have been made in the corundum industry during 1901; one, the manufacture of an artificial corundum by the electric furnace treatment of bauxite and the other, the development of the recently discovered corundum deposits 25 miles southwest of Boseman, Gallatin County, Mont.

In the Montana deposits the corundum occurs in grains and crystals, from minute particles to a size 2 in. and more in length and 1 in. in width. Mill tests by Mr. L. S. Ropes of the Montana Corundum Co. have shown about 20% mineral in the rock and tests on the finished product indicate that it has a very good abrasive efficiency. The corundum is readily cleaned, affording a high-grade commercial product, and a complete plant is being installed for treating the ore and preparing the product for the market. The corundum mined by the Canada Corundum Co. at the Craig mine, Raglan township, Ontario, which occurs somewhat similar to the Montana deposits, is now quoted on the market. Recent tests[1] of the commercial product from this mine, show that it is a satisfactory abrasive, and indicate that the superficial alteration observed on the corundum first obtained is disappearing as mining is carried deeper. The ore occurs in syenite, and as is also the case with the Montana ores, both othoclase and biotite have to be removed in the cleaning process. The Canadian and Mon-

[1] Private communications.

tana deposits are very extensive and if the present price of corundum of 8@10c. per lb. is maintained the product should be marketed in quantity at a fair profit.

In the Southern fields, development is continued of the corundum ore occurring in the bands of gneiss near the summit of the Blue Ridge in Clay County, N. C., and the adjoining Towns County, Ga. During 1901 these deposits produced considerable corundum but it is yet too early to state definitely to what extent they can be operated. The garnet associated with the ore has to be separated before the best commercial corundum can be attained and the low percentage of corundum in the rock is a factor which increases the cost of production. With one exception the large corundum mines now owned by the International Emery & Corundum Co. in Macon and Clay counties, N. C., and Rabun County, Ga., were idle, while the Corundum Hill mine, at Callasaja, Macon County, N. C., was operated to a small extent throughout the year. Large deposits of corundum occur in these properties which are capable of producing the best quality corundum in quantity. The Toxaway Co., of Sapphire, N. C., owning a large tract of land in southwestern Transylvania and southeastern Jackson counties, has done a little development work on the mine formerly operated by the Sapphire Valley Corundum Co. and a number of promising deposits of corundum were exposed. The North Carolina Corundum Co. is opening a mine at Buck Creek, Clay County, adjoining the property of the International Corundum Co. The corundum is said to occur in quantity. The National Abrasive Manufacturing Co., owning deposits in Jackson and Macon counties, N. C., has not operated them recently but has confined its attention to the production of garnet from Sugar Loaf Mountain, Jackson County.

The development of the new corundum deposits and the known occurrence of this mineral in quantity should supply the full demand of the domestic market. Including imports, about 16,000 tons of corundum and emery are consumed annually in the United States and of this 500 tons are corundum. At the present price of 8@10c. per pound for corundum a small quantity only will be called for, but with a slight decrease in price a greater demand will arise at the expense of the emery. A small amount of corundum is imported into the United States from India but not enough to make any material difference in home production, and with an increased domestic output of corundum of good quality it is probable that importation would cease.

What effect the manufacture of artificial corundum from bauxite by the Norton Emery Wheel Co. will have on the production of corundum, cannot yet be told, but much depends upon the question of cost. This company has erected a large plant at Niagara Falls, N. Y., and a portion of its output will be placed on the market.

In the emery field, the Chester mines have been purchased by the Ashland Emery & Corundum Co. and the Hampden Emery Wheel Co. has entered the Peekskill emery field as a producer. The Chester emery still retains its high quality and is often designated as a corundum. The Peekskill emery, while not showing as high an abrasive efficiency as the Chester emery, possesses good abrasive qualities and for some purposes is fully as satisfactory as the best Chester emery or corundum. The spinel, which replaces the larger proportion

of corundum in this ore, has a good cutting edge and breaks with a rough fracture. This product gives good satisfaction when made into a vitrified wheel. A large increase in the production of Peekskill emery is anticipated and when thoroughly cleaned and prepared it should replace much of the imported ore. If the emery contaminated with garnet is kept separate, there should be no difficulty in obtaining a product which when cleaned can be manufactured into a vitrified wheel. A large quantity of crude Turkish and Naxos emery ores continues to be imported into the United States, due primarily to the low price at which it can be placed on the docks at Boston, New York or Philadelphia, as it is brought over as ballast. These imports amount to nearly 12,000 tons per year and the total domestic consumption barely exceeds 16,000 tons. There is thus ample opportunity for a decided increase in the production of emery in this country to replace at least a portion of that imported. This may be said of corundum also, for with a production of 1,000 or 1,500 tons a similar amount of emery would be replaced and even with a slight decrease in price of the corundum, a much larger quantity would be used.

The demand for corundum and emery is increasing, due to the large increase in general manufacturing, as well as to the improved methods of making the many varieties of corundum and emery stones and wheels, as oilstones, scythestones, hones, etc. Emery wheels of larger size are now made and in the near future they will probably rival some of the larger grindstones. These large emery wheels are made entirely by the silicate process and are used for saw gummers. It is a question whether the large vitrified emery wheels could be made cheaply enough to compete with large grindstones. Furthermore, many of the purposes for which these larger grindstones are used require a slower cutting than emery would give. Smaller grindstones, especially for household purposes, are being replaced by corundum and emery wheels which are manufactured in considerable quantity. There is no apparent reason why an export trade of American corundum should not be developed as none is produced elsewhere, except a very small quantity in India. The Canadian product would be on equal terms with that of the United States.

The cleaning of corundum ores is now done by an automatic system. The Southern corundum, and emery calls for a somewhat different process than that applied to the Canadian and Montana ores; with the Montana ore a larger proportion of the impurities are removed by concentrators as the corundum is more readily separated from the other minerals in the crushing. It is necessary however to eliminate as much of the feldspar as possible, otherwise the material will fuse and the abrasive efficiency of the vitrified wheel be lessened. Where the mineral attached to the particles of corundum is more or less micaceous it can only be removed by the "Muller process," in which one grain of corundum is made to grind against another and thus wear away the softer material.

In determining the percentage of corundum in an ore the mistake is still being made of reckoning the total percentage of alumina (Al_2O_3) in the sample as corundum. This is incorrect, as many impurities contain high percentages of alumina. Garnets contain about 20% Al_2O_3 and as they have often been mistaken for corundum, considerable care should be taken in examining the sample.

The following method of determining the percentage of corundum in an ore as used by Pratt & Boltwood, of New Haven, Conn., has thus far proved satisfactory. The material is crushed in an iron mortar to pass through a 14-mesh sieve and sampled; 2 g. of the sample are taken and treated with concentrated hydrochloric acid on the water bath for two hours. The residue is then filtered, dried, and fused one-half hour with 6 g. sodium carbonate mixture (two parts Na_2CO_3, one part K_2CO_3) in a platinum crucible over an ordinary Bunsen burner. The fused mass is extracted with hot water and the solution decanted through a filter. The filter paper is dried and ignited in a platinum dish, the residue from treatment with hydrochloric acid is added to the dish, and the whole treated with an excess of concentrated hydrofluoric acid. The excess of hydrofluoric acid is removed by evaporation on the water bath and the residue is treated with hot water, and finally transferred to an ashless filter paper which with its contents is dried, transferred to a weighed platinum crucible, ignited, cooled and weighed. The increase in weight (residue) is calculated as pure corundum.

There has been practically no change in the uses of corundum and emery for the manufacture of wheels, blocks, stones of various shapes and sizes, emery paper and grains or powder, although there has been some change in the shape of the blocks and stones. Where corundum is transparent it is used for cutting into gems. The artificial abrasives, carborundum and crushed steel, have not cut into the corundum and emery trade to any considerable extent as, so far, they are filling particular fields of their own. However, should corundum be produced in much larger quantities, carborundum will be one of its strongest competitors. With emery, carborundum has been a competitor, but on account of the greater cost of the carborundum, it has not thus far made much inroad on the emery trade. Crushed steel, which is used in the stone cutting trade, particularly for marble and granite, has a field that is not entered by either corundum or emery.

The Ashland Emery & Corundum Co. was recently incorporated under the laws of New Jersey, with a capital of $3,000,000. The emery companies taken over are the following: Ashland Mills Emery Co., of Perth Amboy, N. J.; Diamond Mills Emery Co., of Philadelphia; Jackson Mills Emery Co., of Easton, Pa.; Walpole Emery Mills, of South Walpole, Mass.; Hampden Emery Mills, of Chester, Mass.; and the Levant Emery Co. It is stated that the output of the company approximates 12,000 tons of crushed imported emery ore per annum, 5,000 tons of native ore, and 2,000 tons of corundum. The company owns emery mines at Chester, Mass., and at Peekskill, N. Y.

EMERY.—*Greece.*—The Naxos emery is found as masses in limestone, and contains 93·5% Al_2O_3. The deposits are worked by the inhabitants of the communities of Apiranthos and Koronis, who own the mining rights and who sell the product to the Government at a uniform price amounting to $18·55 per ton. There has been a decided increase in the quantity of Naxos exported during the years 1900 and 1901, due to the facility in the shipping operations at Syra, whereas formerly in Naxos the difficulties of the shippers with laborers, and the danger incurred by the steamers loading in an open roadstead were very great. The quality of the mineral is now of better grade than formerly, although the

price remains the same, being $20·25 per metric ton, which includes the Government tax of $1 per ton. The emery as received in Syra is selected for exportation, and does not contain the residue of the small stones and rubbish which formerly was indiscriminately shipped at Naxos. The trade promises to flourish, as 6,023 tons, valued at $130,000, were exported during 1900, and over 3,000 tons were exported in the first three months of 1901. The quantity exported in 1900 was distributed as follows: 1,760 tons to Hamburg, 1,670 tons to Liverpool, 1,380 tons to Rotterdam, 1,000 tons to Boston, and the remainder to Odessa.

III. CRYOLITE.

The importations of cryolite into the United States during 1901, as in previous years, were derived from the mines in Greenland, and are given in the subjoined table. These shipments were made by the Pennsylvania Salt Manufacturing Co., of Natrona, Pa., which possesses the exclusive privilege to import this mineral into North and South America. The remainder of the output of the Ivigtut mines is shipped to Copenhagen.

IMPORTS OF CRYOLITE INTO THE UNITED STATES FROM 1890 TO 1901, INCLUSIVE. (a)

Year.	Long Tons.	Value.	Year.	Long Tons.	Value.	Year.	Long Tons.	Value.	Year.	Long Tons.	Value.
1890..	7,129	$95,405	1893..	9,574	$126,688	1896..	3,009	$40,056	1899..	5,879	$78,676
1891..	8,298	76,350	1894..	10,684	142,494	1897..	10,115	135,114	1900..	5,437	72,768
1892..	7,241	96,932	1895..	9,425	125,368	1898..	6,201	88,501	1901..	5,883	70,886

(a) The values are those reported by the Custom House and represent the estimated cost at the mines. There being no United States Consul at shipping point in Greenland, a *pro forma* invoice is prepared for Custom House purposes, wherein the value represents only a small part of the actual cost at buyers' factory.

The value of cryolite in the United States is stated to be $80 per ton of 2,240 lb., and results from the following items: Cost at the mine in Greenland, royalty to Danish Government, ocean freight, inland or domestic freight, cost of separating the pure cryolite, grinding and packing in barrels, and other minor expenses.

According to a report furnished by the Danish Government the total production in Greenland was 8,874 metric tons in 1899, and 8,960 metric tons in 1900.

IV. ALUMINUM.

The production of aluminum in the United States continues to be supplied by the sole producer, the Pittsburg Reduction Co., of Niagara Falls, N. Y., and during 1901 the quantity produced was practically the same as in the previous year, being 7,150,000 lb. The demand for the light metal in the electrical trade, particularly for purposes of conduction, and in the metal trade as a substitute for zinc and brass continues to be large. The subjoined tables give the production, imports and exports of aluminum in the United States and other of the principal countries in the world.

PRODUCTION, IMPORTS, AND CONSUMPTION OF ALUMINUM IN THE UNITED STATES.

Year.	Production.			Imports.	Exports.	Consumption. (b)
	Pounds.	Value.	Per Lb.	Value.	Value.	Value.
1897	4,000,000	$1,400,000	$0·35	$4,731	(a)	$1,404,731
1898	5,200,000	1,690,000	0·325	4,879	$239,997	1,454,882
1899	6,500,000	2,112,500	0·325	14,840	291,515	1,835,825
1900	7,150,000	2,288,000	0·32	47,688	281,821	2,053,847
1901	7,150,000	2,238,000	0·31	104,168	183,579	2,158,589

(a) The exports from the United States were not reported by the Bureau of Statistics in this year. (b) The consumption each year includes a certain amount of manufactures imported; while the production represents the crude aluminum only. The bulk of the imports is in crude condition.

The statistics of aluminum production in Europe are not authoritative, several of the important companies being unwilling to make their figures public. The *Metallgesellschaft*, of Frankfort-on-Main, gives the following statistics for Europe in its last annual report, to which we have added our own figures for the United States, and those of C. Le Neve Foster for England previous to 1900.

ALUMINUM: WORLD'S PRODUCTION AND COMMERCE. (IN KILOGRAMS.)

Year.	Germany.	Switzerland.		England.	France.			United States. (a)		Total Production.
	Imports.	Production.	Exports.	Production.	Production.	Imports.	Exports.	Production.	Imports.	
1896..	591,500	700,000	661,100	130,000	370,000	7,012	192,768	589,676	316	1,789,676
1897..	942,400	800,000	706,000	610,000	470,000	6,360	224,000	1,814,388	854	3,394,448
1898..	1,104,000	800,000	677,300	310,000	565,000	5,972	187,955	2,358,705	27	4,033,705
1899..	922,000	1,300,000	604,200	559,000	1,000,000	8,468	256,242	2,948,381	24,323	6,807,381
1900..	943,400	2,500,000	571,200	500,000	1,500,000	8,000	324,000	3,243,219	210,833	7,743,219

(a) The United States has been an exporter of aluminum for several years, but these exportations were not enumerated by the Bureau of Statistics of the Treasury Department until 1898, in which year they amounted to $239,997. (b) C. Le Neve Foster, British Mineral Statistics for 1897.

Prices.—The quotations for aluminum ingots per pound at the close of 1901 were as follows: 99·75% Al, 33@37c.; 90 to 99% (impurities Fe and Si) 31@34c.; nickel-aluminum metal (aluminum with less than 10% Ni) 33@39c; special casting alloy (containing over 80% Al), 27@35c. The import duty on aluminum in the United States is 8c. per pound on ingot and 13c. per pound on sheet and manufactured.

PROGRESS IN THE ALUMINUM INDUSTRY IN 1901.

BY JOHN B. C. KERSHAW.

Production.—The number of works for production of aluminum has been increased from 8 to 9—during 1901—by the completion of the new factory at Shawinigan Falls in Canada, for the Pittsburg Reduction Co. It is unlikely that this factory will increase the American output of the metal seriously, before the end of 1902. Owing to the falling off in the demand for calcium carbide during 1901, the Schweizerische Gesellschaft f. Elektro-chemische Industrie of Basel, has decided to take up the manufacture of aluminum.

The figures for the actual amount of aluminum produced in 1900 and 1901, by the American and European factories, are again based on estimates—and not on official returns. The Neuhausen, and other European companies still

refuse to furnish figures for their output in 1900 and 1901, and as pointed out in THE MINERAL INDUSTRY, Vol. IX., p. 20, estimates based on the power available in the European works are wholly misleading.

TABLE I.—DETAILS OF ALUMINUM WORKS IN EUROPE AND AMERICA.

No.	Name of Company.	Locality of Works.	Horse Power.		Process.	Capital.
			Available	In Use.(a)		
1	The Pittsburg Reduction Co.	Niagara Falls	.....	10,000	Hall	.....
2	The Pittsburg Reduction Co.	Niagara Falls	.....		Hall	.....
3	The Pittsburg Reduction Co.	Shawinigan Falls	6,000	(?)	Hall	.....
4	The British Aluminium Co.	Foyers	14,000	5,000	Heroult	$3,360,000
5	Société Electro-Metallurgique Française	Le Praz	12,500	5,000	Heroult	2,880,000
6	Compagnie des Produits Chimiques d'Alais	St. Michel	6,000	2,000	Hall & Minet	.....
7	Société Anonyme pour l'Industrie de l'Aluminium	Neuhausen	4,000	4,000	Heroult	$3,077,000
8	Société Anonyme pour l'Industrie de l'Aluminium	Rheinfelden	5,000	5,000	Heroult	
9	Société Anonyme pour l'Industrie de l'Aluminium	Lend Gastein	5,000	(?)	Heroult	

(a) With the exception of the American and Canadian works, all these works manufacture other products in addition to aluminum.

The figures given in Table I. show that 26,000 H.P. is actually developed in these six factories, and assuming that only 0·617 kg. aluminum is produced per H.P. day, the capacity of these European works is over 5,200 tons per year. The highest estimate of their 1900 and 1901 production is however 4,600 tons and it is by no means certain that even this figure has been attained. The production at Foyers is however stated to be growing, and it is now three or four times greater than in 1896 and 1897. An estimate by a fairly reliable authority of the Neuhausen Co.'s production in recent years gives 1,000 tons in 1898, 1,500 tons in 1899 and 2,500 tons in 1900. Of the latter total, 1,000 tons is estimated to have been produced at Neuhausen, and the balance at Rheinfelden and Lend Gastein. The total European production in 1900 is estimated at 4,000 tons. The Metallgesellschaft of Frankfort published the following figures for aluminum production in 1900: Neuhausen, Rheinfelden and Lend Gastein, 2,540 tons; Foyers, 510 tons; St. Michel and Le Praz, 1,530 tons; Niagara Falls, 3,230 tons. *Total,* 7,810 tons (metric tons of 2,204 lb.). The actual 1900 production of aluminum was therefore probably between 7,000 and 7,500 tons, and the 1901 figures, if they could be obtained, would probably show a slight advance upon those for the preceding year.

The new plant of the Pittsburg Reduction Co. at Shawinigan Falls consists of two 3,000-H.P. turbines, each direct coupled to two 1,000-K.W. generators, giving a total available power of 6,000 H.P. The supply canal is 1,000 ft. long, by 100 ft. wide, and 20 ft. deep. It ends in a fore-bay 125 ft. above the two power-houses, to which the water is carried by three pen-stocks each 9 ft. in diameter. The main power-house of the Shawinigan Water & Power Co. contains two 6,000-H.P. turbines. The second power-house is smaller, and contains only the Pittsburg Reduction Co.'s generating units, whose works are 175 ft. above the power generating station. Aluminum conductors are used to convey the power. In order to protect the bare aluminum cables from the effects of exposure, a covered passageway has been built over the cables for the whole of the distance (about 400 ft.). This is the first practical recognition in America, that aluminum as a conductor does not resist exposure as well as copper; and

this erection of a covered way for the aluminum cables, is highly significant in its bearings upon the future of the metal as an electrical conductor. The works at Shawinigan Falls are stated to have cost $250,000 and this locality has been selected for the site of the new factory, on account of the adjacent deposits of corundum.

As regards finance, the Aluminium Industrie Aktien Gesellschaft, of Neuhausen, still remains the most successful of the companies whose accounts are available for comparison. The gross profits in 1900, amounted to $406,200 and this company has paid 12·5% for 1900, as compared with 13% for 1899. The valuation of their works is as follows: Neuhausen, $960,000; Rheinfelden, $1,140,000; Lend Gastein, $720,000. All the patents owned by this company have been written off in the accounts and the reserve fund now stands at $67,000. The total capital is $3,077,000.

The British Aluminium Co.'s report for 1900, is far less satisfactory reading for the shareholders, but as all the ordinary shares in this company are stated to be held privately, the loss to the outside public is less serious than it might have been. Owing to an error in the 1899 stock taking, to excessive capital outlay on the carbide works and to the increased cost of fuel and other raw materials in 1900, the company finds itself with $17,200 less profit than in 1899. The amount standing to the credit of the profit and loss account is therefore carried forward, and the preference shareholders have to go without the 7% dividend.

With regard to variations in cost and sale price of aluminum during 1901, there is little to report. The representatives of the leading European companies, and of the Pittsburg Reduction Co., have however recently held a meeting, in order to arrange for the future regulation of output and price. This can only mean an advance in price, and it is therefore probable that aluminum has touched bottom as regards cost to the consumer, until a cheaper raw material than refined alumina is used for the reduction process.

The following are the November, 1901, American prices for aluminum: 99% Al and over, 33 to 37c. per lb.; 90 to 99% Al (impurities, Fe and Si), 31 to 34c. per lb.; drawn rod, and wire, ·0000 to No. 6, B. & S. Gauge, 39·5c. per lb. There is a deduction of 7c. off the list prices, for rod and wire, with 20,000-lb. orders; and aluminum for transmission lines, therefore, costs 32·5c. per lb. in America. The import duty on aluminum in the United States is 8c. per lb. on ingot metal, and 13c. per lb. on sheet and manufactured metal; so the Pittsburg Reduction Co. and its customers are well protected from European competition.

The November price list of the Foyers company gives the following figures:

Ingot metal	Bars 98-99% Al	27·8 cents per lb.
	Special for steel makers	27·8 cents per lb.
	Special alloy	27·8 cents per lb.
	Wolframium, alloy	33·0 cents per lb.
	Romanium alloy	33·0 cents per lb.

Three cents extra per lb. is charged on the above ingot metal for a guarantee of over 99% Al.

The average sale price of the Pittsburg Reduction Co.'s production, worked out to 32·7c. per lb. in 1899, and to 32·3c. per lb. in 1900.

No very noteworthy figures relating to the efficiency of the process by which aluminum is produced, have been published during 1901. An anonymous writer in a London journal[1] has stated that at Foyers 12 E.H.P. hours were now yielding 1 lb. aluminum. This is equivalent to 0·909 kg. per E.H.P. day, or 0·76 kg. per H.P. day; and is an advance upon the earlier published figure, of 0·617 kg. aluminum per E.H.P. day.

With regard to patent litigation, the year 1900 has witnessed two decisions of importance. The application made by the British Aluminium Co. to the English courts, praying that an extension of time for the Heroult patent might be granted, failed, and the patents owned by this firm therefore lapse in 1902. In America the long drawn-out litigation between the Electric Smelting & Refining Co. of Cleveland, and the Pittsburg Reduction Co., has been settled by a judgment in favor of the latter company. This action was commenced in 1897, and was based upon an alleged infringement of the Bradley patents issued in 1892, and owned by the Cleveland company. The most important event of the year is the granting of patents to Hall, of the Pittsburg Reduction Co., for improvements in the method of preparing bauxite for the reduction process. At present the cost of the refined alumina is one of the chief items in the total cost of manufacturing aluminum and no great reduction in the cost of the metal can be expected until this heavy item of expenditure is lessened. Hall proposes to prepare bauxite for the reduction process by submitting it to a preliminary heating in an electric furnace for some hours, in presence of carbon and aluminum. The ferric oxide and silica are reduced to the metallic state and form a heavy alloy with the aluminum, which when cooled can easily be detached from the mass. The new Hall procedure may be widely adopted if the cost of treatment is not too high. Blackmore has patented during 1901 a method of reducing alumina by means of calcium carbide; the alumina being used as raw material in a bath of fused cryolite and lithium chloride. The cost of working this process is stated to be only 7c. per lb., but until further particulars are published, this statement must be accepted *cum grano salis.* Moody and Tucker have also been conducting researches upon the action of calcium carbide on alumina, and they find that if calcium carbide be present, the oxide can be reduced to aluminum by carbon in presence of the electric arc. Such reduction does not occur when calcium carbide is absent.[2]

UTILIZATION.—*Electrical Conductors.*—The use of aluminum as a substitute for copper for bare overhead transmission lines has attracted much attention throughout 1901, and in America especially, this outlet for the metal is becoming of marked importance. The difficulty with regard to the low and variable tensile strength of pure aluminum has been overcome by the use of stranded cables. The addition of small amounts of copper or iron in order to increase the strength of the metal is now recognized as a mistake, since it seriously reduces the conductivity and renders the line less resistant to weather influences.

[1] *The Engineer*, March 22, 1901.
[2] *Journal of the Society of Chemical Industry*, October, 1901.

In Europe progress in the use of aluminum as an electrical conductor is less rapid and Italy is the only country which yet possesses overhead bare aluminum transmission lines, working in connection with a central power generating station. The Neuhausen and the Foyers companies both use aluminum as a conductor within their own works, but these are private installations and are not worked upon a commercial basis. At the Glasgow Exhibition in 1901, aluminum was employed for the outdoor lighting and 10,000 yd. of bare wire are said to have been used for the arc-lamps which were run on 500-volt circuits. Here again the trial was not a commercial one, for the British Aluminium Co. loaned the wire required for this work, to the Exhibition authorities.

The Niagara Falls Power Co. has used the new metal for the second three-phase transmission line, 22 miles in length, between Niagara Falls and Buffalo. Three cables have been erected, each consisting of 37 strands. The resistance of each cable is ·032 ohm at 0°C., the sectional area is 500,000 cm. and the tensile strength is 25,000 lb. per sq. in. The estimated loss of power when transmitting 10,000 H.P. at 22,000-volts pressure, is 7%. The original copper cable contained 19 strands. The spans have been increased from 75 to 112 ft., and the pressure on both lines, which run for many miles parallel, has been raised to 22,000 volts. By this means the capacity of the two lines has been raised to 30,000 H.P. and it is hoped that shortly all of this power will be disposed of in Buffalo, and its neighborhood.

Hoopes[3] has stated that aluminum collects less snow in bad weather than copper. This observation, if correct, may be an effect due to the different specific heats of the two metals, as these stand in the ratio 100 : 47, that of aluminum being the higher. Hoopes recognizes that first cost is only one factor of the problem relating to the use of aluminum in place of copper for conductors, and he states that reliability, durability, and cost of erection are other factors of almost equal importance. With regard to the first, he states that the early breaks in America with aluminum were due to the use of alloys, and that none have occurred since the pure metal was used. As regards durability, he states that aluminum is only attacked chemically by HCl, Cl, and NaOH, and that in these cases a protective coating of Al_2O_3 will be formed. In his opinion, the cost of erecting aluminum wires should not exceed that of copper, because it is lighter, and longer spans with fewer poles can therefore be used. The experience gained in my own experiments, will not allow me to support all of these opinions. Hoopes also states that pure aluminum is now alone used in the United States for wire drawing, it having been apparently recognized that the alloys of aluminum with iron or copper are not so durable as aluminum alone, although the tensile strength of these alloys is greater.

The Italian transmission line mentioned above, extends between Sarno, Pompeii, and Forre Annunziate. The total power transmitted is only 450 H.P. and the voltage is low, being 3,600. Three aluminum conductors are in use, 1·8, 9·0 and 2·0 miles in length, respectively.

An important but anonymous report upon the bare overhead aluminum lines

[3] *The Street Railway Review*, Jan. 15, 1901.

erected in 1899 for the electric lighting of Northallerton, England, appeared in March, 1901.[4] For this installation, wire testing 98·1% Al with a conductivity of only 51 (copper, 100), is stated to have been used. The joints were made by means of screwed sockets of brass. These held well, but they gradually failed owing to the formation of oxide. The copper and aluminum joints, made by twisting the two wires together, lasted only six months. The extra cost of erecting and maintaining the aluminum network of wires, as compared with copper, is stated to have more than balanced the saving in first cost.

Some of the statements in this report have been disputed by the representatives of the British Aluminium Co. and repeat orders for aluminum wire are said to have been given by the Northallerton Electric Light & Power Co.

A minor use of aluminum for conducting purposes is reported in connection with the equipment of the new electro-chemical laboratory at Victoria University, Manchester, England. In this case aluminum has been used for some of the leads, and the joints have been made with an ordinary blowpipe, by a method which appears to be similar to that patented by Heraeus, details of which are given in THE MINERAL INDUSTRY, Vol. IX., p. 29.

A new transmission line of aluminum is being erected by the Snoqualmie Falls Power Co. in California. The new line will extend from the power station at the Falls to Seattle and Tacoma, distant 32 and 44 miles respectively. The new line will require 125 tons of the metal and it is intended to transmit 12,000 H.P. at 30,000-volts pressure.

With regard to the aluminum wires erected in Chicago in November, 1899, in connection with the telephone fire-alarm system, the city electrician reports, that these are answering well and that no special troubles have yet been experienced with them.

During the discussion upon my paper before the London Institution of Electrical Engineers in January, 1901,[5] Mr. J. Gavey gave some interesting details relating to the trials of aluminum by the post-office authorities in Staffordshire, England. In December, 1900, between 18 and 20 miles of aluminum wire were in use, 15 miles of which were erected in the "Potteries." Within 14 days of the erection of this wire, a heavy gale was experienced, resulting in eight or ten breaks in the spans. These breaks were attributed to variations in the mechanical or chemical constitution of the wire. Similar breaks were experienced at first with the aluminum wire used for telephone purposes in California by the Pacific Telephone & Telegraph Co. The weight of the wire used in Staffordshire was 78 lb. per mile; the diameter was 1·24 mm., the tensile strength was 12·56 tons per sq. in. and the specific resistance was 2·974 ohms.

In a recent letter, Mr. J. Gavey, the English post-office electrician, informs me that the post-office authorities have been investigating the cause of the failure of the aluminum telegraph lines erected in December, 1900. The experiments show that the limit of elasticity of aluminum under constant stress is much diminished. A wire breaking under the ordinary conditions of trial at 325 lb.,

[4] *Electrical Review* (London), March 8, 1901.

[5] THE MINERAL INDUSTRY, Vol. IX., p. 31, and the *Journal of the Proceedings of the Institution of Electrical Engineers*, Vol. XXX., 1901.

with a maximum extension of 0·5 in., when submitted to a constant stress of 220 lb. broke at the end of 525 hours, the permanent extension being 2·54 in. The results given above are highly important in their bearing upon the use of aluminum for overhead conductors.

In the same discussion Prof. Forbes stated that two lengths of aluminum wire, drawn from Foyers and Neuhausen metal respectively, had been exposed at Fettercairn, Scotland, for 18 months and 3 years, and that in December, 1900, both wires were in good condition. Mr. Ristori made a similar report regarding the aluminum conductors in use at Foyers.

As regards the total weight of aluminum used in 1900 and 1901, for conducting purposes, no reliable figures can be given. As already stated, the largest use of aluminum for this purpose is in America, and Hoopes states that two recent orders placed in that country have amounted together to 1,250,000 lb. It is therefore evident that half a dozen such orders would absorb a very large portion of the annual output of the Niagara works. The break in the price of copper, which has occurred during 1901, will however affect the sale of aluminum for conducting purposes; since with copper again at £50@£55 per ton, there will be little inducement to use the lighter metal, until a further reduction in its cost has been brought about. As pointed out on page 23, this reduction in the cost of aluminum is now within sight. The price at which ingot aluminum must be sold to equal electrolytic copper at £55 per ton, can be calculated by aid of the following formula, in which P.p. represent the price, C.c. the conductivity, and S.s. the specific gravity, of copper and aluminum respectively:—

$$S \times P \times c = s \times p \times C.$$

Taking the following values: S = 8·93, C = 100, P = £55 per ton; s = 2·68, c = 59, p = x, and substituting these in the equation already given we obtain: $8{\cdot}93 \times 55 \times 59 = 2{\cdot}68 \times x \times 100$, and $x = 8{\cdot}93 \times 55 \times 59 \div 2{\cdot}68 \times 100 =$ £109·40 per ton or 23·4c. per lb.

Whether aluminum will ever be sold of the requisite degree of purity at this price, remains to be seen.

Balloons and Boats.—The interest in aluminum as the lightest known metal has been transferred by the exploits of M. Santos Dumont from the sea to the air, and the metal or its alloys is being used by builders for the construction of the framework of the majority of the navigable balloons now being experimented with. Count Zeppelin's air-ship, in the construction of which aluminum was used, has not indeed been heard of during 1901, but other vessels of similar design have been much to the front. M. Santos Dumont, the Brazilian who circumnavigated the Eifel Tower and won the Deutsch prize, is believed to have used aluminum alloys largely in the construction of his air-ship. M. Roze, of Paris, also is said to be employing 15,000 ft. aluminum rod and tubing, for the framework of his new navigable balloon. This vessel when completed will possess two cigar-shaped balloons enclosed in an aluminum framework, each frame being 140 ft. long and 22 ft. in diameter.

With regard to the use of aluminum for boat building, this metal was used for

the deck plates of the English racing yacht Shamrock II. Some difficulty was experienced by the builders at first in handling these plates, due to lack of knowledge of the properties of aluminum.[6] The aluminum deck was covered with thin wood, to act as a protection and to afford the requisite foothold. The American racing yacht Independence also was built with deck plates of an alloy of aluminum, of a tensile strength of 35,000 lb. per sq. in. These plates were covered with canvas put on with marine glue, in order that they might be protected from the action of the salt water. The ultimate goal of these plates and of those of Shamrock II. is probably the scrap heap; for it was reported that the New York scrap aluminum market had been disorganized in October, by the sale of the deck plates of the old cup-yacht Defender. These plates were so badly corroded that the metal remaining was of little value. It is indeed now generally recognized that aluminum will not stand the action of salt water for any length of time, even when covered with a protective coating.

Cycles and Motor-cars.—The use of aluminum alloys in motor-car construction is extending; and according to Richards,[7] Corbin of Paris is turning out 7 tons of aluminum castings per week, chiefly for automobile builders. Care is necessary in cleaning and preserving these portions of the framework of the vehicles, and the use of oil is recommended to protect the alloys employed, from the effects of moisture or mud. This would seem to indicate that automobilists have wisely recognized that aluminum alloys, though light, are not resistant to all weather conditions, and the disappointment if corrosion should occur will be less fatal than in the case of the boat-building industry, in which expectations of the value of the new metal were unduly raised.

Printing.—The substitution of aluminum for stone in lithographic work is believed to be increasing and some interesting letters[8] have been published from lithographic firms using aluminum in their printing machines. The chief advantages over stone were stated to be economy in first cost, and greater speed in obtaining impressions. It is admitted that experience is required, before good results can be obtained with aluminum and here, as in the use of the metal for other purposes, it is unwise of those interested in the sale of aluminum to press unduly its superior advantages. Practical hints upon the precautions to be observed in using aluminum for lithographic work will be found in the publication named below.[9]

Foundry and Metallurgical Uses.—The use of aluminum in foundry and casting work is one of the most important outlets for the metal. According to Heroult, 2,500 tons of the lower grades of aluminum are now used per annum in the steel industry alone. The affinity of aluminum for oxygen, which renders it of value in steel casting, is also the basis of its use for producing heat by the Goldschmidt process. The Chemische-Thermo Industrie, formed to exploit this process, now places on the market the mixture of aluminum powder and ferric oxide under the trade name of "Thermit." The mechanical details of the application of the method to rail-welding and to repairs of propellor shafts have been much improved during 1901. The temperature attained by

[6] *The Aluminum World*, May, 1901.
[7] *Journal of the Franklin Institute*, February, 1901.
[8] *The Aluminum World*, January, 1901.
[9] *Ibid.*, January to December, 1901.

the molten iron, when this process is worked under the most favorable conditions, is said to approach 3,000°C., and it is evident that at such a temperature, welding work can be carried out, which would be most difficult or impossible to perform, by any other means, as for example, the repairing of propellor shafts in mid-ocean. The application of the method to the reduction of refractory oxides does not appear to have advanced beyond the laboratory stage excepting in the case of chromium and its alloys, which are now produced by the Goldschmidt Co., at Essen. The method however is applicable to the reduction of practically all of the heavy metallic oxides, and any of these metals can now be prepared at a moderate cost from its corresponding oxide. When using an excess of aluminum, alloys of aluminum and the concerned metal are obtained. In this way Guillet has recently prepared alloys of aluminum and tungsten.[10] Vanadic oxide has also been reduced with success by the Goldschmidt process. The details of the method and its application in this particular instance, have been described by Smith.[11] Vanadium added to steel increases its tensile strength, and Smith gives tests showing a gain of 10 tons per sq. in., as the result of an addition of 0·56% V to tool steel.

Miscellaneous Uses.—An aluminum alloy capable of taking a high polish is now being used for constructing the bright parts of oil stoves, and in France and in Italy a large and growing industry in the new metal is being built up by the manufacturers of funeral wreaths. During 1901 a proposal has been made to use thin aluminum foil in place of paper for printing and other purposes, but the cost would be prohibitive. The use of aluminum for large castings is extending. An English firm which has made a special feature of this work, recently cast a motor-engine cylinder and bed-plate, weighing 300 lb. If cast in iron, this would have weighed 800 lb.; the saving in weight was therefore considerable. At the Buffalo Exposition, 1901, the Pittsburg Reduction Co. exhibited an octagonal house, 22 ft. in height, and covering 15 sq. ft., built completely of No. 24 sheet aluminum.

The use of aluminum for the manufacture of novelties is a special branch of the business which has been energetically pushed in the United States. Small articles of aluminum, such as trays, paper cutters, calendars, mirrors, boxes, etc., stamped with the name of the advertising firm, find ready acceptance at the hands of customers, and so long as the metal retains its brightness, they form most useful advertisements. This use for the metal might be developed more vigorously in Europe where novelties in aluminum are the exception rather than the rule.

Alloys of Aluminum.—Two new alloys have appeared during the year and are known as nickel-aluminum and "minckin." The former consists mainly of aluminum with nickel and copper, the alloy having a sp. gr. of 2·86. The difficulty of alloying aluminum of low melting point with nickel of high melting point is surmounted by alloying the aluminum first with copper, which prepares it to take up the nickel later. Tests have shown a tensile strength for nickel-aluminum of 16·44 tons per sq. in. Minckin is an alloy similar to the so-called "new silver" but con-

[10] *Comptes Rendus*, May 6, 1901. [11] *Journal of the Society of Chemical Industry*, December, 1901.

tains more nickel. Ordinary "new silver" contains 26% Ni, an amount beyond which it was formerly difficult to go, owing to the development of gases in the mass. Minckin is being largely used on account of its resistance to the corrosive action of weak acids and alkalies.

Partinum, the alloy of aluminum and tungsten, is being manufactured in Paris and the employment of this alloy, which is said to possess a tensile strength of 49,000 lb. per sq. in., is believed to be growing. The laboratory production of alloys of aluminum and tungsten by the Goldschmidt method, has already been referred to.

Albradium, an alloy of copper, nickel, zinc, phosphorus, and aluminum, is manufactured by a company in London, and samples of this alloy were shown at the Paris (1900) Exposition. Magnalium, the alloy of aluminum and magnesium, is manufactured by the Deutsche Magnalium Gesellschaft and is protected by German Patent No. 113,935 of 1899. The alloys containing from 2 to 10% Mg are found to be the most valuable, and their ductility and malleability can be much increased by rolling and annealing. The resistance offered by this alloy to the effect of salt water or to "weathering" is low, and it cannot therefore be employed for marine work, or for outdoor decorative work in bad climates.

Jos. W. Richards has published some information concerning the alloys of aluminum and zinc.[12] The hardest and strongest of the aluminum and zinc alloys is that containing two parts of aluminum to one of zinc, while the alloy with three of aluminum to one of zinc is the most generally useful and has special application for making scale beams, surveying and astronomical instruments, gear wheels, etc. With decreased percentage of zinc, the hardness and the tensile strength of the alloy are decreased, thus affording material for special application where the previously mentioned alloys are too hard. Alloys containing less aluminum than zinc, do not appear to have any specially valuable mechanical properties.

Tetmayer has published researches bearing on aluminum bronzes.[13] The tests were carried out in the Laboratory of the Zurich Polytechnic at the request of the Neuhausen Aluminium Co. Three series of experiments were planned, but only those relating to aluminum bronzes were completed. The specific gravity of the bronzes first rises and then falls as the percentage of aluminum increases. The maximum strength for soft alloys was obtained with 3·4% Al, and for hard alloys with only 1·4% Al. Aluminum bronze containing 10% Al with 1·5% Fe and Si, is too brittle to be of any practical value. As regards the use of aluminum bronze for bearings, the hard variety with less than 89·60% Cu stood the tests well, while the soft bronzes with less than 6% Al, heated and lost rapidly in weight.

In a contribution to the French Academie des Sciences[14] M. Le Bon has described experiments upon the effect of minute quantities of mercury on aluminum. Such an alloy was attacked by water and by all acids, with progressive and complete oxidation of the aluminum. These results show the necessity for great care in the manufacture of aluminum, for minute traces of metals other

[12] *The Aluminum World*, May, 1901.
[13] *Revue de l'Electricite* (Berne), Aug. 31, 1901.
[14] *Comptes Rendus*, January, 1901.

than mercury, may have equally disastrous results upon the durability of the metal when exposed to water or damp air.

Soldering and Welding.—Patent solders still continue to be manufactured and sold, although, on account of the remarkably high affinity of aluminum for oxygen, no metal can be used with it for jointing purposes that will not form the electro-negative element of an electric couple, when the joint is immersed in water or is exposed to a damp atmosphere. For this reason, all soldered joints under these conditions are certain in time to become weak and to show disintegration. The only two satisfactory methods of jointing aluminum are therefore the mechanical, and the method devised by Heraeus. The former has been used for most of the American transmission lines, the Mac-Intyre sleeve joint being that usually employed. The latter, known as the autogenous weld, can be easily learned and applied.

In the discussion upon the paper by Morrison referred to below, Bubb stated that the method of jointing aluminum wires by the autogenous method, could be easily mastered, and that any man with a blowpipe could make satisfactory joints after 30 minutes' practice.

Gavey gave some interesting details relative to the jointing of aluminum wires, in the discussion already referred to.[15] He stated that the question of soldering seemed to be solved so far as the mere soldering of joints was concerned, but unfortunately the heat necessary for the soldering annealed the wire and reduced its strength exactly one-half. Ultimately the wires were run out in the full length of the coil, each coil being erected on an insulator, and the joint soldered in a little loop, so that the annealing of the wire itself had no injurious effect on the strength of the portion that was suspended.

The method described above, for overcoming the difficulty caused by the loss in tensile strength due to the heating of the wire when jointing, in conjunction with the autogenous weld, will probably be generally adopted for overhead wires in the future.

Plating.—Further details of the Wachwitz method of plating aluminum have been published during 1901. This method depends upon rolling plates of aluminum and copper together while heated and is therefore a mechanical process. In the first rolling, the aluminum is used as a very thin foil, and in the second rolling a thicker plate of aluminum is used with the copper. The method is said to yield good results and the finished copper-aluminum sheets can be used for various industrial purposes. Nothing further has been published concerning the exhibit of an electro-deposited plate of aluminum at the Paris (1900) Exposition, or the method by which it was produced. An interesting method of purifying crude aluminum, by using it as a molten anode in a bath of fused fluorides, with molten aluminum as cathode, has been patented by Hoopes.[16] This process can however never occupy the place in the aluminum industry that electrolytic refining has taken in the copper industry, for silicon and iron, the impurities of commercial aluminum, are practically valueless, and can never pay for their recovery in an electrolytic bath. The Hoopes patent has been

[15] *Proceedings of the Institution of Electrical Engineers*, Vol. XXX., Part 149.

[16] United States Patent No. 673,364, 1901.

assigned to the Pittsburg Reduction Co. As regards the difficulties met with in plating upon aluminum, Ryan[17] recommends a preliminary treatment with phosphoric acid before immersion in the plating bath. The selection of aluminum plates of uniform composition is also held to be a necessity for the attainment of good results, since silicon and iron are often accumulated in spots, and these give rise to local circuits in the electroplating bath.[18]

Properties.—The properties of aluminum in certain of its commercial forms have already been discussed elsewhere in this section under the headings of *Alloys* and *Electrical Conductors.* As regards electrical conductivity, Hoopes states that pure aluminum only is now used for transmission cables, and that at 70°F. the relative conductivity of aluminum and copper may be taken as 62·9:100. The following tests, recently given to the public, were made by the officials of the Pittsburg Reduction Co. in 1898, and are interesting as showing the marked effect of small amounts of impurity upon the conductivity of unannealed aluminum:—

Composition.	Resistivity.	Composition.	Resistivity.
99·66% Al	2·45	97·16% Al	2·89
99·56% Al	2·58	94·39% Al	3·01
98·77% Al	2·84		

The conductivity is of course the reciprocal of these figures, but in the absence of details as to the size of the wire used in carrying out the tests, it cannot be expressed in the usual way, namely, as percentages of the conductivity of electrolytic copper of equal sectional area and length.

With reference to the resistance offered by aluminum and its alloys to weather influences, the exposure tests that I commenced at St. Helens and Waterloo in 1899, are still being continued, and the further results of these will be published in the course of 1902. Details of the figures obtained during the first 10 months' exposure were given in THE MINERAL INDUSTRY, Vol. IX., p. 31. The contributions of Prof. G. Forbes and Mr. E. Ristori to the discussion which followed the reading of my paper in January, 1901, have already been referred to under *Electrical Conductors.* As regards the composition of commercial aluminum now being placed upon the market as first grade metal, the following figures have been published for the product of the British Aluminium Co.: Al, 99·58%; Si, 0·18%; Fe, 0·24%. This compares favorably with the Pittsburg Reduction Co.'s 99·66% metal.

Prof. Wilson, in a paper read before the London Institution of Electrical Engineers in December, 1901, gave a large number of chemical and physical tests of aluminum and its alloys, a portion of which is reprinted on page 32.

It will be noticed in the above table, that the conductivities range from 48·6% to 61·5%; the latter being obtained with commercially pure aluminum containing 0·14% Si and 0·31% Fe. The breaking strain of this wire was 28,200 lb.; while the strongest alloy was that containing 1·08% Cu (No. 22 in the Table) the breaking strain in this case being 45,900 lb.

Morrison, in his paper read before the same Society at Glasgow, dealt with the

[17] German Patent No. 116,819, 1899.

[18] *Electrical Review* (New York), May 18, 1901.

PROF. WILSON'S TESTS OF ALUMINUM AND CERTAIN ALLOYS OF THE METAL.

Number of Specimen.	Composition.							Specific Resistance in 10^{-6} Legal Ohms at 15° C.	Conductivity per cent. In Terms of Matthiessen's Standard Taken to be $1·696\times10^{-6}$ Legal Ohms at 15° C. for Copper.	Percentage Extension with 16,250 Lb. per Sq. In. of Cross Section.	Limit of Elasticity in Lb. per Sq. In. Cross-Section.	Breaking Load in Lb. per Sq. In. Cross-Section.	Average Linear Coefficient of Expansion per 1° C. between 16° C. and 100° C.	Specific Gravity before Annealing at 435° C.
	Si. %	Fe. %	Cu. %	Ni. %	Mn. %	Zn %	Al. %							
16	·31	·37	·11	....	....	....	99·21	2·92	58·0	·177	19,500	26,600	·0000236	2·719
4	·38	·25	·16	....	....	....	99·21	2·88	58·9	·200	17,900	25,700	·0000234	2·748
13	·38	·25	1·58	....	....	....	97·79	3·34	50·7	·194	32,500	39,000	·0000239	2·748
14	·40	·31	1·86	....	....	....	97·43	3·25	52·1	·183	32,500	40,600	·0000240	2·748
15	·40	·40	2·61	....	....	....	96·59	3·34	50.7	·186	34,500	43,500	·0000241	2·764
1	·38	·22	·17	....	....	·62	98·61	2·86	59·2	·286	23,600	28,100	·0000245	2·720
2	·43	·28	·30	....	....	1·20	97·79	2·94	57·6	·171	20,300	30,500	·0000241	2·728
5	·43	·39	·09	....	....	2·04	97·05	3·07	55·2	·171	20,700	26,000	·0000230	2·749
7	·37	·25	·05	·75	....	....	98·58	3·05	55.6	·189	20,300	29,700	·0000246	2·723
8	·35	·29	·09	1·19	....	....	98·08	3·24	52·3	·237	23,600	33,700	·0000236	2·731
20	·37	1·10	·06	2·25	....	....	96·22	3·18	53·2	·189	20,300	38,600	·0000234	2·756
24	·35	1·16	·09	....	....	....	98·40	2·97	57·1	·194	20,300	31,300	·0000248	2.731
3	·37	·28	·59	....	....	·59	98·17	3·06	55·3	·180	22,300	30,500	·0000227	2·732
6	·39	·31	·63	....	....	1·20	97·47	3·12	54·3	·237	24,400	30,900	·0000244	2 742
17	·35	·53	·10	·83	....	·90	97·27	3·03	56·0	·191	18,300	31,700	·0000236	2·751
12	·31	·50	·19	1·09	....	·73	97·09	3·33	50·9	·197	21,500	31,700	·0000236	2·738
18	·43	·40	·21	1·13	....	1·94	95·89	3.24	52·4	·189	22,300	34,500	·0000245	2·763
19	·35	·20	·11	2·01	....	1·77	95·47	3·26	52·0	·160	20,300	36,200	·0000225	2·770
11	·39	·56	·24	2·31	....	·38	96·12	3·48	48·7	·194	24,400	34,500	·0000235	2·741
22	·37	·43	1·08	1·29	....	....	96·83	3·41	49·7	·146	36,600	45,900	·0000252	2·747
21	·39	2·57	·10	1·39	....	....	95·55	3·24	52·3	·194	24,400	42,200	·0000222	2·770
10	·32	·54	·02	....	·05	....	99·07	3·09	54·8	·191	22,700	29,200	·0000222	2·732
9	·31	·35	·03	....	·35	....	98·96	3·30	51·3	·183	22,300	30,500	·0000231	2·733
23	·44	·56	·09	....	1·78	....	97·13	3·49	48·6	·186	24,400	35,300	·0000230	2·750
Pure	·14	·31	Commercial aluminum.					2·762	61·5	·190	19,376	28,200	·0000234	2·715
	Hard-drawn copper.....							.....	98	·102	27,850	64,000	·0000170	8·914

manufacture of aluminum at Foyers and with the well-known uses of the metal, but added little information to what has already been published in this and previous volumes of THE MINERAL INDUSTRY. With reference to the use of aluminum as an electrical conductor, he stated that the wires at Foyers after four years' use, showed no appreciable deterioration.

V. ALUM AND ALUMINUM SULPHATE.

ALUM, ARTIFICIAL.—The production of alum and aluminum sulphate in the United States during 1901 increased very largely, the reported output of aluminum sulphate amounting to 74,721 short tons, as compared with 61,678 short tons in 1900, while that of crystallized alum was 7,755 short tons, as compared with 20,531 short tons in 1900. The apparent large decrease in the production of crystallized alum results from the method of calculation necessary previous to 1901, the year in which statistics of production were first collected directly from the producers.

The statistics of the production of alum and aluminum sulphate given in the above table previous to 1901 are computed from the consumption of bauxite and cryolite in the United States, and the production of aluminum, it being assumed that what is not used for aluminum is used for making the sulphates. The yield of both American and imported bauxite is well known, and consequently

UNITED STATES PRODUCTION AND IMPORTS OF ALUM.

Year.	Production.								Imports. (a)		
	Alum.			Aluminum Sulphate.			Total Reckoned as Alum. Sh. Tons.	Total Value.	Short Tons.	Value.	Per Ton.
	Short Tons.	Value.	Per Ton.	Short Tons.	Value.	Per Ton.					
1897..	15,456	$463,680	$30·00	46,355	$1,158,875	$25·00	79,600	$1,622,555	2,373	$78,883	$33·24
1898..	18,791	563,730	30·00	56,663	1,416,675	25·00	97,302	1,980,405	(b) 893	16,187	18·13
1899..	27,276	845,556	31·00	81,805	2,106,479	25·75	127,430	2,952,035	(b) 858	14,953	17·49
1900..	20,531	615,930	30·00	61,678	1,480,272	24·00	105,743	2,096,202	(b) 1,109	22,283	19·07
1901..	7,775	233,250	30·00	74,721	1,793,304	24·00	.....	2,026,554	(b) 1,091	20,781	19·05

(a) Includes alumina, alum, alum cake, aluminum sulphate, aluminous cake, and alum in crystals or ground. (b) There was also imported in 1898, 1,205 short tons ($76,884) of aluminum hydrate, or refined bauxite, in 1899, 1,926 short tons ($119,202), in 1900, 2,207 short tons ($148,332), and in 1901, 1,986 short tons ($146,462).

this is an accurate method of determining the production in so far as it is expressed in terms of crystallized alum. The division into crystallized alum and aluminum sulphate is estimated, and consequently is only approximate. However, since it is apt to be misleading to report the entire production as crystallized alum, of which really only a comparatively small amount is made, the statistics for 1897 to 1900 have been reported in the modified form. Any apparent discrepancy is thus accounted for. The following companies produced one or both of these salts during 1901: The General Chemical Co., The Pennsylvania Salt Co., Harrison Brothers, Charles Lenig & Co., The Erie Chemical Co., The Cochrane Chemical Co., The Merrimac Chemical Co., and The Detroit Chemical Co. The production of alum shale in the United Kingdom in 1900 was 1,308 long tons (£164), as compared with 5,820 long tons (£728) in 1899.

Market Conditions.—New York prices of alum during 1901 were $1·65@$1·75 per 100 lb. for lump, $1·85 ground, and $2·50@$3 powdered. Aluminum sulphate, owing to competition, was unsteady at $1·15@$1·25 per 100 lb. for the commercial quality, and $1·50@$2 for the purest quality.

NATURAL ALUM.—The Alum Co., at Bullahdelah, New South Wales, during 1900 shipped 1,915 long tons of alunite (£5,745) to the United Alkali Co.'s works at Runcorn, near Liverpool, England, as compared with 921 long tons (£2,763) in 1899.

AMMONIA AND AMMONIUM SULPHATE.

THE production of ammonia (reported as its equivalent sulphate salt) and ammonium sulphate by by-product coke oven plants in the United States during 1901 is estimated at 66,000 short tons, and for 1900, at 63,800 short tons, which shows the active development of this industry due chiefly to the increase in the number of by-product coke ovens now in operation. The manufacture of ammonia and ammonium sulphate in the United States and in Europe during recent years is discussed in complete detail in the paper by Dr. F. Schniewind, on "The Manufacture of Coke, with Especial Reference to the Markets for By-products," which is given elsewhere in this volume.

The imports of ammonium sulphate into the United States for the past five years are given in the tables of imports and exports at the end of this volume.

According to the annual report of the Chief Inspector of Alkali Works, etc., for the United Kingdom, the production of ammonium sulphate during 1901 amounted to 220,000 long tons, as compared with 210,000 long tons in 1900. The details of production are given in the subjoined table:—

PRODUCTION OF AMMONIUM SULPHATE IN THE UNITED KINGDOM. (IN TONS OF 2,240 LB.)

	1898.	1899.	1900.	1901.		1898.	1899.	1900.	1901. (a)
Gas works	129,590	136,529	138,000	148,500	Coke works	11,568	15,209	15,000	19,000
Iron works	18,000	17,963	18,000	16,000					
Shale works	37,264	38,780	39,000	36,500	Total	196,357	208,481	b210,000	220,000

(a) Estimated. (b) Of this amount England furnished 134,000 tons, Scotland 73,000 tons, and Ireland 3,000 tons.

The world's production of ammonium sulphate during 1901 exceeded 523,000 metric tons, valued at $26,673,000. Of this quantity, Germany contributed 130,000 tons and France 38,000 tons. The product is used mainly in the manufacture of fertilizers. In Germany there are 4,245 Otto-Hoffman coke ovens for the saving of by-products.

Average price per 100 lb. of gas liquor ammonium sulphate, basis 25%, in New York in 1899, 1900 and 1901, was as follows:—

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Average.
1899	$2·716	$2·663	$2·667	$2·810	$2·975	$3·337	$3·190	$3·111	$3·065	$2·975	$2·850	$2·995	$2·988
1900	2·925	2·956	3·081	2·981	2·887	2·840	2·725	2·825	2·755	2·750	2·775	2·775	2·856
1901	2·788	2·801	2·813	2·700	2·731	2·750	2·721	2·745	2·769	2·819	2·820	2·794	2·771

ANTIMONY.

THERE was no material change in the antimony industry in the United States during 1901 except the very large decrease in the imports of ore due to over-importation in 1900. The control of the production and trade continues to remain in the hands of Mathison & Co., of London, with works at Chelsea, Staten Island, N. Y., and of the affiliated concern, the Chapman Smelting Co., with works at San Francisco. Practically all of the domestic ore smelted is treated at the San Francisco works, which refines as well antimony regulus imported from Japan. The supply of antimony for domestic consumption as metal or as lead alloy is derived from the following sources: (1) hard lead produced as a by-product from the smelting or refining of lead ores and bullion of both domestic and foreign origin, (2) imported ores or crude antimony, (3) imported metal or regulus, and (4) domestic ores. The quantity produced from domestic ores during 1901 was 50 tons, which is an insignificant proportion of the total domestic consumption. The only ore of commercial value in the United States is the mineral stibnite (Sb_2S_3) which was produced to the extent of a few hundred tons from mines in California, Idaho, and South Dakota. Many stibnite deposits occur in other Western States as well, but on account of the high cost of transportation to smelters they cannot be operated at a profit.

The details of imports, production, and consumption of antimony in the United States, from 1897 to 1901, inclusive, are given in the subjoined table. There was a small export of 25 tons antimony ore during 1901, valued at $1,536.

IMPORTS, PRODUCTION, AND CONSUMPTION OF ANTIMONY IN THE UNITED STATES.

Year.	Imports.					Production.				Consumption
	Metal or Regulus.		Ores.		Total Value.	In Hard Lead. (a)	From Domestic Ores	From Imported Ores. (b)	From Imported Regulus or Metal.	Total Supply.
	Pounds.	Value.	Pounds.	Value.		Short Tons.	Short Tons.	Short Tons.	Short Tons.	Sh. Tons.
1897	1,146,606	$46,955	5,502,132	$167,373	$214,328	2,217	245	599	1,141	4,202
1898	2,025,133	143,909	3,725,222	50,256	194,165	2,118	250	870	1,052	4,290
1899	3,160,697	240,988	3,982,133	47,841	288,829	1,586	234	1,041	1,495	4,356
1900	3,632,843	285,749	6,035,734	78,581	364,330	2,476	151	1,599	1,827	6,053
1901	3,640,506	254,529	1,731,497	24,068	278,597	2,235	50	864	1,837	4,486

(a) Estimated at 25% of the total quantity of hard lead produced. (b) Estimated at 40% extraction, from average of 52·5% antimony in ore.

The table given above shows the constantly increasing quantity of antimony obtained from foreign ores and regulus, which is due mainly to cheap ocean freight rates from foreign countries, where the ores are mined at a low cost.

WORLD'S PRODUCTION OF ANTIMONY ORE. (a) (IN METRIC TONS.)

Year.	Austria.		France and Algeria.		Hungary.		Italy.		Japan. (e)	Mexico. (f)	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Tons.	Value.
1896	905	$38,702	6,383	$84,509	1,361	$22,572	5,086	$60,590	827	3,231	$32,098
1897	864	38,255	5,466	83,588	1,800	34,568	2,150	27,657	348	5,873	71,835
1898	679	22,867	4,571	69,462	2,201	20,219	1,931	43,822	1,006	5,982	98,815
1899	410	15,244	7,592	130,493	1,965	34,205	3,791	44,892	712	10,382	115,292
1900	201	7,171	7,996	115,978	2,378	37,720	7,609	72,468	81	2,813	23,319

Year.	New South Wales.		New Zealand.		Portugal.		Queensland.		Spain.		Turkey. (b) (d)	United States.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Tons.	Value.
1896	135	$9,170	21	2,250	595	$26,775	(c)	.....	54	$1,385	100	196	$4,750
1897	172	18,060	10	768	417	28,063	(c)	.....	354	6,483	400	454	16,000
1898	84	4,580	Nil.	.....,	245	6,736	Nil.	.....	130	2,149	(g)	(g)	.....
1899	332	13,470	Nil.	.....	59	2,123	41	$1,000	50	1,560	1,178	544	20,000
1900	252	12,145	3	505	38	554	Nil.	.....	30	900	267	300	10,500

(a) The foreign statistics are derived from the official reports of the several governments; those for the United States were collected specially for THE MINERAL INDUSTRY. (b) Export figures. (c) Not yet reported. (d) Fiscal years. The Turkish statistics are of doubtful accuracy. (e) Mostly crude antimony. (f) Export figures, values in Mexican dollars. (g) Statistics not collected.

WORLD'S PRODUCTION OF ANTIMONY METAL. (a) (IN METRIC TONS.)

Year.	Austria.		France and Algeria.		Germany. (d)		Hungary. (b)	Italy.		Japan.	Servia.		United States.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons	Value.	Tons.	Value.	Tons.	Tons.	Value.	Tons.	Value.
1896	423	$52,655	969	$130,217	1,326	$156,111	500	$59,813	536	$72,440	517	.....	.....	556	$84,712
1897	424	51,350	1,033	141,857	1,665	210,744	523	63,360	404	57,072	824	.....	.....	844	133,124
1898	343	42,286	1,226	163,200	2,711	302,992	855	109,681	390	62,550	233	163	$23,782	1,130	203,750
1899	271	33,772	1,499	243,840	3,149	347,200	940	139,502	581	87,900	229	180	26,280	1,275	262,004
1900	153	14,844	1,573	246,090	3,338	473,750	888	122,400	1,174	154,360	(e)	(c)	(c)	1,750	369,915

(a) From the official reports of the respective countries. (b) Crude antimony and regulus. (c) Not reported. (d) Includes manganese. (e) Statistics not yet available.

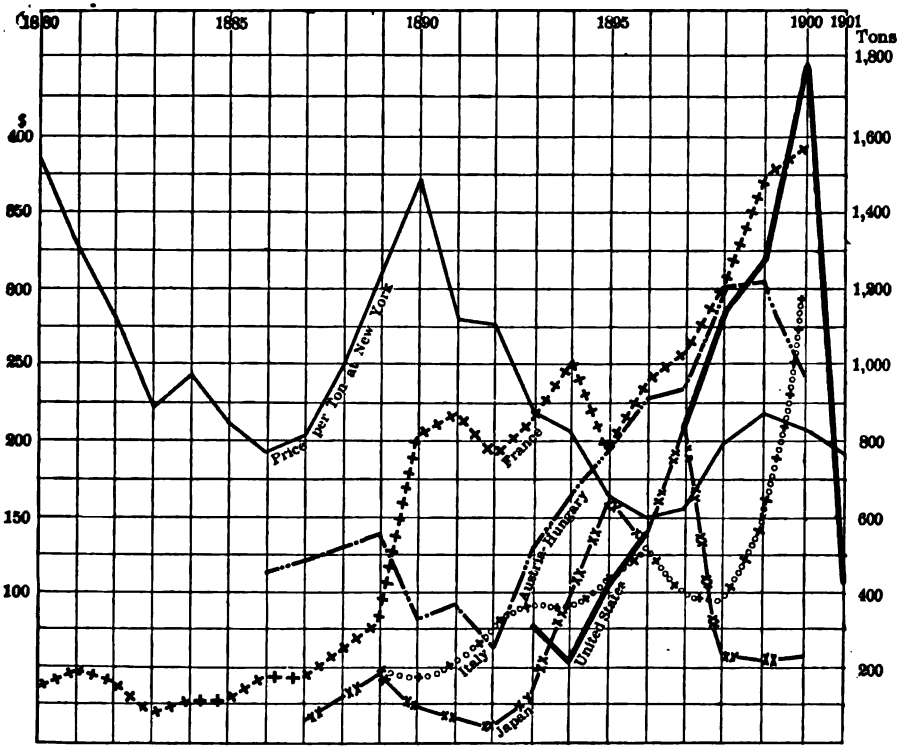
Algeria.—The production of antimony in Algeria in 1900 amounted to 180 tons, valued at $10,470. Of this 106 tons were shipped from the Taya mines to Marseilles, the freight rate being £11 4s. per ton, which corresponds to 3s. 10d. per unit. The extent of the mining concessions in this province is reported at 2,632 acres.

Chile.—The exports of antimony from Antofagasta in 1900 amounted to 302 long tons, valued at £22,569; there were also exported 877 long tons of antimony ore valued at £65,510.

France.—The principal center of the antimony industry in France is at Auvergne, Brioude (Haute-Loire). The smelting works are at Couches (Cantal), Blesle, and Biroude, and the ore supply is derived from the mines Licoulne-Bessade, Loubelhac, Ouche, and Couches. The ore is very low grade, averaging but 7 or 8% antimony, and is roasted in a special furnace to produce the volatile antimonous oxide, which is collected in a condensation chamber. The waste gases are used again, thus diminishing the loss. The product, consisting of Sb_2O_3 with traces only of Sb_2O_4 and Sb_2O_5, is used in part for the preparation of antimony compounds for dyeing purposes, which is exported, amounting in value to $80,000 annually, and in part for the production of the so-called "star antimony" metal by heating the oxide in a crucible with coal and an alkaline slag. The metal gives an analysis of 99·94% Sb. The mines operated by the three smelting works produce annually from 3,000 to 4,000 metric tons of antimony ore.

Italy.—During 1900 there were 692 metric tons of antimony ore extracted from the mines at Meria, Ersa, and Luri, in the Cap Corse district north of Bastia. The bulk of the output was obtained from the Meria mines. The ores are hand picked and cobbed by women at so low a cost as to preclude even crushing machinery. The best grade of the product assays 60% metallic antimony.

Japan.—In recent years the production of crude antimony in Japan has fallen off considerably owing to the competition of the refined product of China. To counteract this effect a new refining plant on modern principles has been constructed near Osaka. The output of antimony in Japan is derived chiefly from the mines at Nara, Ehrme, and Yamaguchi, about 25 miles from Kioto. The



THE WORLD'S PRODUCTION OF ANTIMONY IN METRIC TONS.

production of antimony metal during 1900 was 349 metric tons, and the exports amounted to 377 metric tons.

Nova Scotia.—The St. Helens Metal Recovery Co. is erecting a 30-ton plant at West Gore, and will purchase ore as low grade as 8% Sb, allowing also for 75% of the gold content. The McDougal mine has been intermittently worked from 1880 to 1892, when it was closed down. The ore is stibnite associated with pyrite, arsenopyrite, and galena, and occasionally with the oxidized antimony minerals, valentinite and kermesite. Several analyses of second grade ore showed from 1·14 to 41·13% Sb and from $1·50 to $80 gold per ton, the average being 12% Sb and from $20 to $30 gold per ton. The 3,000 tons of ore shipped pre-

viously to 1892 is reported to have averaged 12% Sb and from 2 to 3 oz. gold per ton. Several shafts have been sunk to nearly 200 ft., and 76,000 sq. ft. of ground on the vein have been stoped. Formerly only high-grade ore of 50% Sb content was shipped.

Peru.—The exports of crude antimony from Mollendo during 1899 amounted to 67 metric tons, which were shipped for the most part to England.

Servia.—A French company, with offices in Paris, is operating the antimony smelting works of Kostajnik, on the Drina river, in the western part of the country. Work has been actively carried on for several years, and the annual capacity of the works amounts to about 600 metric tons of product.

Spain.—The San José and the Genara mines, near Villabarcú, in the Caurel range of mountains, produced over 40 tons of concentrated antimony sulphide during 1900. The ore carries a certain amount of silver, and the mining rights cover areas of 162 and 337 acres, respectively. Antimony ore is also found in the Caurel mine, in Caurel, and at the Perseverance mine, near Brollon. The Biobra group of mines, near Biobra, in Orense, was operated during 1898-99, and more than 80 tons of ore were extracted; later the mines were shut down, but it is stated that operations are shortly to be resumed by an English company.

The New York Antimony Market in 1901.—The trade in antimony metal during 1901 was rather dull, and the market had a drooping tendency. The year opened with Cookson's selling at 10c.; Hallett's, 9c.; Hungarian, Italian, and U. S. Star, at 8·75c. Prices declined slowly throughout the year, and the closing quotations were: Cookson's, 10c.; Hallett's, 8@8·25c.; Italian, Hungarian, Japanese, and U. S. Star, 7·75@8c. These figures are quoted for retail lots; larger quantities were sold at a corresponding lower figure. The consumption, though satisfactory, showed but little change from last year. Imports of ore and the United States production declined markedly, while imports of metal or regulus increased to a small extent. There has been a tendency to substitute new and cheaper grades of metal for the standard English brands. Stocks at the end of the year were comparatively small.

AVERAGE MONTHLY PRICES OF ANTIMONY IN NEW YORK. (IN CENTS PER POUND.)

Year.	Brand.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1897....	Cookson's	7·12	7·31	7·87	7·44	7·25	7·25	7·25	8·00	8·00	8·00	7·81	7·81	7·55
	Hallett's	6·80	6·90	7·06	7·00	7·00	7·00	7·00	7·28	7·37	7·50	7·40	7·40	7·14
	U. S. Star	6·80	7·00	7·06	7·22	7·05	6·78	6·87	7·28	7·37	7·50	7·40	7·50	7·15
	Japanese	6·75	6·80	6·75	7·00	6·75	6·78	6·87	7·15	7·25	7·25	7·15	7·18	6·91
1898....	Cookson's	8·00	8·00	8·25	8·37	9·20	9·65	9·75	9·75	9·75	9·70	9·25	9·25	9·08
	Hallett's	7·37	7·56	7·81	7·96	8·04	8·97	9·06	9·06	9·06	9·03	8·81	8·81	8·51
	U. S. Star	7·50	7·59	7·81	7·92	8·64	8·97	9·06	9·06	9·06	9·03	8·81	8·81	8·52
	Japanese	7·44	7·58	7·81	7·90	8·59	8·97	9·06	9·06	9·06	9·03	8·81	8·81	8·51
1899....	Cookson's	9·31	10·25	10·37	10·10	10·50	10·50	10·50	10·50	10·50	10·50	10·50	10·50	10·37
	Hallett's	8·81	9·62	9·75	9·80	10·00	10·00	10·00	9·81	9·65	9·72	9·75	9·75	9·67
	U. S. Star	8·81	9·62	9·75	9·80	10·00	10·00	10·00	9·81	9·56	9·50	9·50	9·50	9·65
	Chapman's	.....	9·62	9·75	9·80	10·00	10·00	10·00	....	....	.....	.....	.....	.....
	Hungarian	.....	.....	9·75	9·80	10·00	10·00	.....	9·75	9·56	9·50	9·50	9·50	.....
1900....	Cookson's	10·50	10·50	10·50	10·50	10·50	10·50	10·50	10·50	10·10	10·00	10·00	10·00	10·34
	Hallett's	9·75	9·75	9·75	9·75	9·69	9·62	9·53	9·50	9·30	9·25	9·25	9·25	9·53
	U. S. Star	9·50	9·50	9·50	9·50	9·50	9·50	9·50	9·50	9·30	9·25	9·25	9·25	9·42
	Cookson's	10·00	10·00	10·00	10·31	10·25	10·25	10·25	10·25	10·12	10·09	10·00	10·00	10·12
1901....	Hallett's	9·12	9·22	8·90	8·94	8·75	8·75	8·75	8·63	8·50	8·47	8·37	8·31	8·74
	U. S. Star	9·25	9·06	8·80	8·73	8·63	8·63	8·63	8·50	8·37	8·34	8·25	8·00	8·69
	Hungarian	.....	8·75	8·75	8·73	8·63	8·63	8·63	8·50	8·37	8·34	8·25	8·00	8·51
	Italian	.....	8·75	8·75	8·73	8·63	8·63	8·63	8·50	8·37	8·34	8·25	8·00	8·51
	Japanese	.....	.....	.....	8·73	8·63	8·63	8·63	8·50	8·37	8·34	8·25	8·00	8·48

Volumetric Determination of Antimony.—A sample (0·5 to 1 g.) is treated with 50 c.c. hot water and 50 c.c. strong HCl, and heated at 70°C., 30 to 60 minutes. Filter to flask, wash with dilute HCl. Add tartaric acid to filtrate, dilute to about 750 c.c., heat to 79°C., and precipitate with H_2S. Filter, wash with H_2S water, transfer precipitate to precipitation vessel with the aid of hot water. The sulphide is warmed with 50 c.c. strong HCl (avoid boiling) until H_2S is no longer evolved. The presence of H_2S is at once detected, if a little cold water be added to the solution, by the reappearance of a precipitate of red Sb_2S_3, the addition in the absence of H_2S causing only a slight milkiness, due to basic chloride. When all H_2S is expelled, the liquid is diluted, the turbidity is removed by just sufficient HCl added drop by drop, and the solution titrated with potassium permanganate.

$$5SbCl_3+16HCl+2KMnO_4=5SbCl_5+2KCl+2MnCl_2+8H_2O.$$

If 5.27 g. of $KMnO_4$ be dissolved per liter of solution, 1 c.c. will equal 1% Sb with 1 g. sample. The end point of reaction is sharply defined.

Atomic Weight of Antimony.—G. C. Friend and E. F. Smith[1] have determined the atomic weight of antimony by passing dry hydrochloric acid gas over 3 g. purified potassium antimonyl tartrate contained in a protected porcelain crucible, which, after half an hour, was heated to redness. The results were remarkably concordant, and averaged 120·353, hydrogen being taken as 1.

Alloys.—Henry Fay and Harrison Everett Ashley (a paper read before the American Institute of Mining Engineers, November, 1901) suggest that on account of the close similarity of the physical properties of tellurium and antimony the former might replace antimony in some of its alloys. The effect of small quantities of antimony on malleable metals, such as copper and gold, renders them hard and brittle, but on lead it imparts the necessary hardness for type metal. With tin it produces valuable alloys, as Britannia metal, and with tin, zinc and copper it forms Babbitt metal for anti-friction bearings. The eutectic mixture of lead and antimony (12% Sb) resists the corrosive action of sulphuric acid, and is used for lining the lead chambers for the manufacture of that acid.

In like manner, tellurium hardens other metals, particularly lead alloys. The freezing temperature of the alloy, Sb_2Te_3 (38·63% Sb and 61·37% Te) yielded the maximum of 629°C.; the freezing points of the two components being antimony, 624°C. and tellurium, 446°C.

[1] *Journal of the American Chemical Society*, July, 1901, p. 502.

ARSENIC.

THE two most important features of the arsenic industry during 1901 were the production of 300 short tons of arsenious oxide by the Puget Sound Reduction Co., at Seattle, Wash., and the decision to close the Devon Great Consols mine, near Tavistock, which has been the chief arsenic producer in England for many years. The main supply of arsenic in the world previous to 1901 was derived almost entirely from the mines in England and Germany. The development of the industry in Canada, which produced 695 short tons in 1901, and the inception of the industry in the United States, as mentioned above, are significant factors in forecasting the future for this branch of the mineral industry.

The consumption of arsenic and arsenical compounds in the United States is indicated by the imports of white arsenic (arsenious oxide, metallic arsenic, and arsenic sulphides in recent years, which are reported in total values as follows: 1896, 5,813,387 lb. ($215,281); 1897, 7,242,004 lb. ($352,284); 1898, 8,686,681 lb. ($370,347); 1899, 9,040,871 lb. ($386,791); 1900, 5,765,559 lb. ($265,500); and 1901, 6,989,668 lb. ($316,525).

THE WORLD'S PRODUCTION OF ARSENIC. (*a*) (IN METRIC TONS.)

Year.	Canada.		Germany.				Italy. (*c*)		Japan.	Spain. (*d*)		United Kingdom. (*e*)	
			Prussia.		Saxony. (*b*)								
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Tons.	Value.	Tons.	Value.
1896...	*Nil.*	.....	1,750	$130,539	882	$90,626	330	$24,400	6	271	$27,100	3,674	$227,415
1897...	*Nil.*	.....	1,924	143,775	1,063	152,122	200	18,600	13	244	29,256	4,282	373,975
1898...	*Nil.*	.....	1,624	121,818	1,053	131,710	215	15,700	7	111	13,320	4,241	268,935
1899...	52	$4,842	1,409	128,678	953	138,572	304	26,483	5	101	12,156	3,880	271,180
1900...	275	22,725	1,585	138,663	829	124,587	126	12,096	5	150	18,036	4,148	335,140

(*a*) From official reports of the respective countries. (*b*) Arsenious acid. (*c*) Metallic arsenic and arsenious acid. (*d*) Arsenic sulphide. (*e*) Arsenious acid.

Market Conditions.—The price for white arsenic at New York varied during 1901 from 4·5c. per lb. in January to 3·5c. in December, the monthly average for the year being 3·92c. Red arsenic from Germany was quoted at 7@7·25c. per lb. in January and February, and at 7c. for the balance of the year, averaging throughout 7·04c. per lb. at New York. Pure Paris green in bulk sold at 12@12·5c. per lb.

Canada.—The production of arsenious oxide in Canada during 1901 was 695 short tons, valued at $41,676, as compared with 303 short tons, valued at $22,725 in 1900. The entire production was made by the Canadian Gold Fields, Ltd., at Deloro, Ont., in connection with the treatment of arsenical gold ores by the bromo-cyanogen process. The concentrates, after the extraction of the gold contained in them, are passed through a cylindrical washer and the arsenical fumes condensed in suitable chambers. The collected fumes are refined in a reverberatory furnace of special design and the resultant arsenious oxide fumes are condensed and collected in a second set of chambers, yielding a product containing 99·4% As_2O_3 of pure white color. Practically all of the arsenious oxide produced at the Deloro works is sold in New York. Despite the claim that Canada can produce arsenic at a lower cost than any other country, the Dominion and Provincial Governments have agreed to give a bounty of $200,000 to aid the industry, and it is fair to assume that the production during 1902 will be greatly stimulated.

Apart from the arsenic and arsenical ores occurring in the United States, there are several chemical and metallurgical by-products rich in arsenic—as speiss from the lead smelters and precipitated arsenic sulphide produced in the purification of sulphur dioxide gas, used in the manufacture of sulphuric acid—which should be utilized in some way to replace the large quantities of arsenic compounds that are imported annually from Europe and Canada.

Portugal.—Arsenious oxide has been produced from arsenic ores of the Pintor mine, Oliveira, in the district of Aveiro, in the following quantities: 1898, 751 metric tons ($65,000); 1899, 1,082 metric tons ($56,657); 1900, 1,000 metric tons ($71,280); and 1901, 1,010 metric tons ($72,350). There is a small importation of arsenic from Germany, which is sold at $35@$40 per ton.

Spain.—The San Miguel mine, near Bustarviejo, in the Province of Madrid, has lately been sold to Don Lorenzo Lulle. This property includes a large deposit of arsenical pyrites which was worked long ago as a silver mine, but subsequently abandoned; later an English company operated it for a time and produced commercial arsenic, but the venture did not prove profitable. With the recent increase in the demand for arsenic and in the price of the metal, it is believed that the property can be operated profitably. The arsenical gold pyrites of the Corunna district average about 20% arsenic and from 10 to 16 dwt. of gold per ton. This property is now being examined for Cornwall capitalists largely interested in the arsenic trade, and the results promise to be of satisfactory nature, as both the gold and the arsenic can be regained. The Métallurgique Hispano-Belge Co. has been recently formed with a capital of $200,000 to operate the auriferous arsenical pyrites deposits near the town of Ferrol, San Vicente de Meirás; the Josefina and Josefina II. mining concessions comprise in all an area of more than 600 acres. A smelting plant has been erected at Badalona, 4 miles from Barcelona, to treat arsenic, lead and copper ores of the district. A separate department is devoted to the treatment of 30 tons of arsenical ore daily. The ore assays 45% As, and from 0·5 to 0·8 oz. gold per ton; galena also occurs in veins containing 53% Pb, 60 oz. silver, and 0·6 oz. gold per ton.

United Kingdom.—The Great Devon Consols mine, near Tavistock, which has been the chief producer of arsenic in England for many years, is being closed. The mine has been worked continuously at least since 1844, and the company has distributed dividends equal in the aggregate to nearly twenty-five times the amount of capitalization. The reasons given for closing the mine are the low price of arsenic and the refusal of the ground landlord to renew the lease.

Electric Furnace Treatment of Arsenical Pyrites.[1]—The Arsenical Ore Reduction Co., of Newark, N. J., has been experimenting with the Westman furnace for the electric reduction of arsenic from mispickel ores. The theory of the process is to subject the ore, a sulpho-arsenide of iron (FeS_2, FeAs) to the heat of the furnace in an atmosphere of nitrogen. The decomposition under these conditions causes the iron to form a fusible mono-sulphide (FeS), which is removed as molten matte while the arsenic is distilled and condensed as a fine powder. The furnace is charged through an air-tight hopper at the top, and the nitrogen and arsenic gases are made to circulate by means of a small fan alternately through two sets of condensers, one at each end of the furnace, thus avoiding the excess heating which would result if one set only were used. An alternating current is passed through two iron electrodes to the matte, which, when molten, is a fairly good conductor. Carl Hering, from his experiments with this furnace, estimates that the cost of producing arsenic at Niagara Falls, N. Y. (electric energy at $20 per kilowatt year) from mispickel ore containing 46% As, would be less than 25c. per hundredweight.

Analytical Determination of Arsenic.—S. Avery and H. T. Beans[2] determine soluble arsenious oxide in Paris green by digesting for five minutes over an open flame 1 g. of the sample with 25 c.c. of sodium acetate solution containing 12·5 g. of the crystallized salt; the cooled solution is diluted to 100 c.c., half of which is filtered off and titrated with standard iodine in the usual way. The study of the action of carbonic acid on Paris green suspended in water showed that the usually accepted maximum amount of arsenious oxide (4%) permissible in Paris green to be used for spraying purposes is a false guide as by hydrolysis and the action of carbonic acid, much of the arsenic in the Paris green is converted into the soluble condition, a fact that explains many of the irregularities observed in the action of Paris green on foliage, as weather conditions might have favored the formation of free arsenic trioxide from a comparatively pure sample of Paris green.

Electrolytic Process for Making Paris Green.—Richard Franchot, of Niagara Falls, has patented a process[3] for the manufacture of Paris green by electrolyzing with a copper anode a solution of calcium acetate and arsenious acid.

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[1] *Electrochemist and Electrometallurgist*, October, 1901.
[2] *Journal of the American Chemical Society*, February, 1901.
[3] United States Patent No. 698,696 of

ASBESTOS.

THERE was a considerable decrease in the production of asbestos in the United States during 1901 from the previous year, the output being 747 short tons, valued at $13,498, as compared with 1,100 short tons, valued at $16,500 in 1900. The value of the product during 1901 is reported at 20% increase above the price for 1900. Practically the entire output was derived from the mines of the Sall Mountain Asbestos Co., at Sall Mountain, White County, Ga., there being but a very small quantity produced by the Berkshire Talc Mining Co., at Hinsdale, Berkshire County, Mass., and by the Pacific Asbestos Co., at Riverside County, Cal. Deposits of asbestos of the chrysotile variety have been reported near Grants Pass, Ore., west of Sims Station, Cal.; near North Wilkesboro, N. C., and near Toccoa, Ga. In Wyoming, the McConnell Asbestos Co., of Pitsburg, Pa., is actively engaged in developing its mines. The H. W. Johns Manufacturing Co., of New York, and the Mannville Covering Co., of Milwaukee, Wis., consolidated their interests on January 1, 1902, under the name of the H. W. Johns-Mannville Co., with a capitalization of $3,000,000. The new company is constructing a plant at Milwaukee for the manufacture of mineral wool and calcined magnesite for special use as non-conducting coverings for boilers, steam pipes, etc.

The price for crude asbestos in the United States during 1901 showed a marked advance from the average price of the preceding year, which was due to the control of the market having been acquired by one manufacturing company in the United States.

PRODUCTION AND IMPORTS OF ASBESTOS IN THE UNITED STATES.

Year.	Production.				Imports.		
	Short Tons.	Metric Tons.	Value.	Value per Metric Ton.	Manufactured.	Unmanufactured.	Total.
1897.....	840	762	$12 950	$16·99	$10.570	$264,220	$274,790
1898.....	885	803	13,425	16·72	12,899	287,636	300,535
1899.....	912	827	13,860	16·76	8,949	303,119	312,068
1900.....	1,100	998	16,500	16·54	24,155	331,796	355,951
1901.....	747	678	13,498	19·91	24,741	667,087	691,828

PRODUCTION OF ASBESTOS IN THE WORLD. (*a*) (IN METRIC TONS.)

Year.	Canada.		Cape Colony.(*c*)		Italy.		Russia.		United States.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
1897.....	27,617	$445,368	47	$490	106	$5,240	1,022	$37,444	762	$12,950
1898.....	21,577	486,227	161	10,185	131	9,000	1,665	60,600	803	13,425
1899.....	22,938	483,299	(*b*)	.....	81	7,264	2,698	97,342	827	13,860
1900.....	27,797	748,431	157	12,785	(*b*)	.....	(*d*)	.....	998	16,500
1901.....	34,554	1,186,434	(*d*)	.....	(*d*)	.....	(*d*)	.....	678	13,498

(*a*) From official reports of the respective countries. (*b*) Not stated in the reports. (*c*) Exports. (*d*) Statistics not yet available.

A comparison of the output of the United States with the quantity of asbestos reported shows the very small proportion of the domestic consumption that is derived from domestic sources. The active developments of asbestos mines in the United States during 1902, notably at Eden and Lowell, Vt., and at Caspar, Natrona County, Wyo., will reduce considerably the ratio of the imported mineral product. In Vermont there are four companies engaged in developing asbestos mines: the New England Asbestos Mining & Milling Co., the National Mining & Development Co., the Tucker Asbestos Co., and the Vermont Asbestos Co. The first named concern has made the most progress, and it is reported by Dr. Joseph Hyde Pratt to have 20,000 tons of asbestos rock on the dumps ready for milling.

The name asbestos is given to the fibrous variety of the minerals amphibole, a calcium and magnesium silicate, and serpentine (chrysotile), a hydrous magnesian silicate. The fibers of the latter, though shorter, are up to 2 in. in length, and are superior in strength and elasticity, consequently the field for its use is much larger. The fibers of the amphibole variety are sometimes 3 ft. in length. Practically all of the chrysotile variety consumed in the United States and Europe is obtained from the noted deposits at Black Lake and Thetford, Sherbrooke County, Ontario, Canada.

The chief use for asbestos is as a non-conductor of heat for boiler covering; fireproof paints for wall plaster; packing for fireproof safes, etc. When non-conductivity of heat and not strength of fiber is required the amphibole variety can be used, but when strength of fiber also is essential, as in the manufacture of cloth felt board, rope blocks, etc., the chrysotile variety is used. Recently asbestos has been used in the manufacture of fireproof bricks, and tests made by the British Fire Prevention Committee (*Stone*, February, 1901) on "gypsine," a fireproof material composed of hydraulic lime, sand, and asbestos pressed into bricks, showed remarkably good results. One side of a 9-in. partition of gypsine bricks set in hydraulic mortar and lightly coated with a layer of fire clay, was submitted for an hour to a temperature which rose to 2,050°F. The material was in no way affected, and the temperature of the outer surface was never sufficiently high to ignite a match held against it.

Canada.—The production of asbestos in Canada during 1901 showed a very large increase over the figures for 1900, both in quantity and value, being 38,097 short tons, valued at $1,186,434, as compared with 29,141 short tons valued at $748,431 in 1900. The variation in the average value per ton is due to the large quantity of asbestic and low-grade fiber that is included in the total output. Of the total production of asbestos in Canada during 1901, the following quantities expressed in short tons were exported: 18,117 to the United States, 3,324 to the United Kingdom, 2,235 to Germany, 2,221 to Belgium, 240 to France, and 588 to other countries; making a total of 26,715 short tons, which is equal to 81% of the total output.

ASPHALTUM.

UNDER this heading are included all mineral bituminous products embracing as well that portion of the residuum from the refining of petroleum which is sold and used as asphaltum.

PRODUCTION OF ASPHALTUM AND BITUMINOUS ROCK IN THE UNITED STATES.
(IN TONS OF 2,000 LB.)

States.	1899.			1900.			1901.		
	Tons.	Value.	Per Ton.	Tons.	Value.	Per Ton.	Tons.	Value.	Per Ton.
Bituminous sandstone:									
California	a 40,321	a $116,097	$2·70	a25,355	a$101,420	$4·30	24,306	$77,661	$3·15
Kentucky	1,783	7,132	4·00	8,922	37,472	4·20	8,942	56,610	6·33
Indian Territory	.....	.....	.....	.....	.....	.....	1,000	4,330	4·33
Total	42,104	$123,229	$2·75	34,277	$138,892	$4·05	34,248	$138,601	$4·05
Asphaltic limestone:									
Utah	250	1,250	5·00	2,550	12,750	5·00	*Nil.*	.....	.....
Indian Territory	10,128	53,172	5·25	1,360	4,080	3·00	2,970	15,375	5·20
Texas	.....	.....	.....	.....	.....	.....	4,000	18,000	4·50
Total	10,378	$54,422	$5·24	3,910	$16,830	$4·30	6,970	$33,375	$4·79
Asphaltum:									
California	a 15,060	a 308,130	20·46	d11,140	218,520	19·62	b 19,988	316,559	15·83
Indian Territory	.....	.....	.....	.....	.....	.....	98	1,000	10·20
Texas	.....	.....	.....	.....	.....	.....	330	19,800	60·00
Gilsonite:									
Utah	3,150	97,650	31·00	3,279	98,370	30·00	c 1,500	46,000	30·67

(a) Statistics of the California State Mineralogist. (b) Includes 1,000 tons of liquid asphaltum valued at $49,850. (c) Estimated. (d) Includes production in Indian Territory.

The production of bituminous sandstone in the United States during 1901 was practically the same as in 1900, the quantity and value being 34,248 short tons ($138,601), as compared with 34,277 short tons ($138,892) in 1900. Practically the entire output was produced from California. The quantity of bituminous limestone produced in 1901, from the deposits of Indian Territory and Texas, amounted to 6,970 short tons, valued at $33,375, as compared with 3,910 short tons, valued at $16,830 in 1900, showing a very large increase. The production of asphaltum in California during 1901, including 1,000 tons of the liquid product valued at $49,850, was 19,988 short tons ($316,559), as compared with 11,140 short tons ($218,520) in 1900. The quantity of gilsonite produced in 1901 is estimated at 1,500 short tons, valued at $46,000, as compared with 3,279 short tons, valued at $98,370 in 1900.

The National Asphalt Co., which was incorporated in 1900 with a capitalization of $22,000,000, divided into 200,000 $50 shares of 6% cumulative preferred stock and 240,000 $50 shares of common stock, was declared insolvent December 28, 1901, and was placed in the hands of receivers. The chief cause assigned for the failure of the combination was the keen competition with which the subordinate companies had to contend, and which left them unable to pay dividends upon their stock, nearly all of which is held by the National Asphalt Co. It is reported that the company will be reorganized on a basis of $25,000,000 stock, of which $15,000,000 is to be preferred and $10,000,000 common.

An interesting note on the use of asphaltum for pavement is the utilization of fine stamp mill tailings from the treatment of copper ore at Lake Superior as a constituent for the paving mixture, which consists of 70% sand tailings, 15% limestone, and 15% asphaltum cement. One pavement company reports the use of 15,000 long tons of the material in 1900, and 20,000 long tons in 1901.

The development of the asphaltum industry in the United States is well set forth in the paper on "The History of the Asphaltum Industry," given later in this section.

THE WORLD'S PRODUCTION OF ASPHALTUM AND ASPHALTIC ROCK. (*a*) (IN METRIC TONS.)

	Austria.	France.		Germany	Hungary.	Italy.	Russia.	Spain.		Trinidad. (*e*)
	Asph. Rock.	Asphaltum	Asph. Limestone. (*b*)	Asphaltum.	Asphaltum.	Asph. Rock.	Asphalt. (*c*)	Asphaltum	Asph. Rock.	
1896	390	17,717	34,394	61,552	2,740	45,456	22,192	1,285	1,117	100,400
1897	300	17,982	30,946	61,645	3,057	55,339	22,222	1,878	1,656	133,310
1898	643	18,832	36,000	67,649	3,125	93,750	12,018	2,354	2,354	108,792
1899	2,635	22,100	39,000	74,770	3,060	81,987	23,051	2,646	2,542	144,340
1900	887	24,400	36,800	89,685	2,900	101,738	(*d*)	2,331	4,198	161,399

	United States.		Venezu'la (Bermudez). (*e*)
	Asphaltum. (*f*)	Asphaltic Rock. (*g*)	
1896....	18,519	39,531	6,197
1897....	24,854	45,233	11,528
1898....	23,306	57,728	*Nil.*
1899....	13,662	50,061	12,014
1900....	8,326	41,029	17,981

(*a*) From the official reports of the respective countries, except where noted to the contrary. The production of gilsonite in the United States and Manjak in Barbadoes is not included. (*b*) France produces a large amount of bituminous shales, used for distilling oil, which is not included in these statistics. (*c*) The statistics for 1896 are official returns furnished by the Department of Mines, St. Petersburg, to C. Le Neve Foster for his Blue Book on Colonial and Foreign Statistics for 1897. (*d*) Not yet reported. (*e*) Exports (crude equivalent) reported by The New Trinidad Lake Asphalt Co. (*f*) Statistics reported by the California State Mineralogist, practically the entire American product being derived from California. (*g*) Statistics based on direct reports from the producers, including asphaltic limestone and sandstone.

NOTE.—There is a considerable production of asphaltic stone in Switzerland of which no account is taken in the above table, the Swiss Government not publishing any mineral statistics.

ASPHALTUM IN FOREIGN COUNTRIES.

Cuba.—The following brief summary of the asphalt deposits of Cuba has been largely obtained from an article in the *Engineering and Mining Journal,* March 8, 1902, entitled "Bitumen in Cuba," by T. Wayland Vaughan. The deposits of asphalt generally occur as veins, pockets or exudations in the form of springs, usually in serpentine rock, but occasionally in limestone. None of the material is now found in its original rock, and it is not at present possible to state from what rock this material has been derived. Bituminous substances, asphalt and mineral tar are found in every province, and the material is generally suitable for use as varnish or as insulating material. Most of the deposits, how-

ever, contain too much asphaltene for use in paving or roofing. While some of the deposits contain large amounts of petrolene, whether or not it is in stable chemical combination has not been definitely determined. It has been suggested that the glance pitches containing large proportions of asphaltene might be mixed with maltha containing a large proportion of petrolene and so make a material suitable for paving.

Province of Pinar del Rio.—The Santa Helena deposit, at Bahia Honda, is said to be of great purity and abundance, and extensive deposits are reported in the Vuelta Abajo district. The Rodas Concepcion and Magdalena mines, at the head of the Bay of Mariel, operated for a number of years, have produced from 1,000 to 1,300 tons annually, all of which has been consumed for fuel or for gas making on the estate of the owner, Don Ramon Balsinde. The deposits are about 36 ft. thick for over 100 ft. in length. A deposit of asphaltum about one mile south of Mariel Bay, which has been quarried to a depth of 50 ft., is a brownish, impure, solid asphalt. Near Banes, between Mariel and Habanas, the San José and Constancia mines have not been worked extensively.

Province of Havana.—The Casualidad asphalt mine is situated 6 miles from Guanabacoa, 9 miles east of Havana, and 2 miles south of the sea. The asphalt occurs in serpentines, diorites, and euphotides, accompanied by veins of quartz and chalcedony, and often copper. The outcrop is traceable for a distance of from 600 to 900 ft. At the surface, the vein was about 1 ft. thick, while at 30 ft. depth it is 9 ft. thick. An analysis shows: Carbon, 34·97%; volatile matter, 63%; ashes or cinder, 2·03%. Specific gravity in three different specimens, 1·142, 1·189, 1·197; streak, dark; powder, brown. The property has not been worked to any great extent and the demand for its products appears to have been limited. The Prosperidad, 6 miles from Havana, on the road to Taposte, has been explored to a depth of 144 ft. by two shafts, and numerous galleries show a horizontal extent of 180 ft. Four other mines near Havana have been worked some years ago, but scarcely more than 600 tons of material were recovered from them. The only mine in the province which is now being operated is the Angela Elmira, located about 5 miles from Bejucal and owned by the West Indies Co., of New York City. The mine was reopened in the latter part of 1900, and regular shipments were made during 1901 to various parts of the United States. The asphalt is hard, occurs in a good sized body in limestone, and carries from 70 to 72% of bitumen. The full analysis made by Dr. L. Saarbach is: Moisture and volatile at 60°C., 2·4%; petrolene, 34·6%; asphaltene, 38·1%; non-bituminous organic matter, 5·4%; silica, 10·2%; iron and alumina oxides, 4·9%; lime, 1·7%; magnesia, 0·2%; sulphur, in mineral combination, 2·4%; alkalies and undetermined, 0·1%.

Province of Matanzas.—About 10 miles northwest of Matanzas, asphalt exudes from small fissures in serpentine on a contact with hard blue limestone, the serpentine forming the hill and the limestone lying on its flank. The deposit has not been developed to any great extent. Another occurrence of asphalt is reported near Guamacaro, between Limonar and Cárdenas, in Cárdenas Bay. There are four asphalt deposits of two grades. The one in the western portion of the bay has been worked for 21 years, and produces a very fine grade of asphalt, which

is used in the United States for the manufacture of varnish, and commands from $80 to $125 per ton of 2,240 lb., delivered in New York City. About 1·5 tons are obtained daily by means of submarine work. A lighter being moored over the 125-ft. shaft, a long pointed iron bar manipulated by a winch is dropped into the shaft repeatedly until a sufficient quantity of the asphalt has been broken, when a diver is sent down to fill a basket with the material thus acquired. The three other mines yield asphalt of a lower grade, suitable for roofing or paving purposes only. No. 4 mine, situated near Diana Cay, 15 miles from Cárdenas, is called the Constancia, and about 20,000 tons have been taken from it during the 20 years of its operation, without any apparent exhaustion of the deposit, which is inclosed within a circle of about 150 ft. diameter. As the depth of water is but 12 ft. about 30 tons per day is obtainable using primitive methods only. Near Sabanillo de la Palma, 30 miles east of Cárdenas, a thick mineral tar oozes into a well sunk into serpentine rock for about 80 ft. in depth. The material is recovered by hand windlass and bucket at the rate of about 20 bbl. per day. Two other tar wells are close at hand and about 1 mile southwest is another area of natural tar springs, one of which has been explored to a depth of 60 ft. One of these wells fired during the last insurrection, burned for four months before it was put out by a heavy rain, and the ground for about 80 ft. about this hole is at present covered with coke. Another tar hole occurs near the Santa Catalina plantation, about 5 miles from the northern coast.

Province of Santa Clara.—The Santa Eloisa asphalt mine, near Loma Cruz, about 9 miles northeast of Santa Clara, is a deposit, about 20 m. deep, by 40 m. wide of unproved length, which exists in a cavity in serpentine rock. The material is a hard glance pitch, and is used in Santa Clara for the manufacture of gas. The following analysis, made by Mr. Frederick P. Dewey, is unfortunately not expressed in terms of asphaltene or petrolene, although the volatile matter may be reckoned as petrolene, and the fixed carbon as asphaltene: Moisture, 1·28%; volatile matter, 45·43%; fixed carbon, 31·75%; ash, 21·54%. Several deposits of more or less liquid asphaltum exist in the vicinity of Camajuani, about 18 miles from Santa Clara, and a deposit of solid asphaltum is known near the Sagua river, about 3 miles from Ranchuelo. Three other deposits are reported in the province.

Province of Puerto Principe.—Both asphaltum and mineral tar have been mined to a limited extent in this province. The present cost of getting the asphalt from the mines to El Estero, Reá, is estimated to be about $13 per ton.

Province of Santiago.—A deposit of solid asphalt, a glance pitch, exists near Puerto Padre, but little or no work has been done to develop it.

Germany.—The production of asphalt in Germany during 1901 was 90,193 metric tons, as compared with 89,685 metric tons in 1900.

Italy.—Italy exported 21,856 metric tons of asphalt during 1901, a decrease of 2,431 metric tons from the export of 24,287 metric tons in 1900.

Madagascar.—Samples of liquid asphalt have been sent to the French colonial office by General Galliene from Ambodiriana, near Ankely Marobaola. The deposit is of very limited extent.

Mexico.—According to Allejandro Prieto, in his *History of Tamaulipas,* large

quantities of asphaltum occur in the State along the interior margins of the Laguna Madre, Morales, and in the vicinity of Sota La Marina. In some asphaltum beds (chapopote) the asphalt is of a dark chocolate character and in a somewhat liquid form, while in others it is an ebony-black color in a compact, solid form, resembling coal. The surface appearance of these deposits indicates the presence of petroleum also.

Trinidad and Tobago.—The exports of asphalt from the Island of Trinidad are given in the following table, for which we are indebted to the courtesy of Mr. Ira Atkinson, treasurer of the New Trinidad Lake Asphalt Co., Ltd. Seven-eighths of the asphalt exported is dug from Pitch Lake, which is leased to the company for a term, of which 28 years have yet to run. Despite the removal of 1,720,000 long tons of asphalt during the past 34 years, there has apparently been very little impression made on the Pitch Lake deposit. The greater bulk of the exports is made by the New Trinidad Lake Asphalt Co., although some 30,000 tons are annually handled by smaller shippers from lands outside the lake. The lake contains no liquid asphalt, but in other parts of the island this variety, from which illuminating and lubricating oils can be distilled, is found widely distributed. Glance pitch, also found in the island, is used for electric insulations and for black varnishes. Manjak, another variety, has recently been discovered in quantity, about 10 miles north of the pitch lake.

EXPORTS OF LAND ASPHALT FROM TRINIDAD. (*a*) (IN TONS OF 2,240 LB.)

Year.	To United States.			To Europe.			To Other Countries.			Grand Total of Exports in Crude Equivalent.
	Crude.	Épuré.	Total Equivalent in Crude.	Crude.	Épuré.	Total Equivalent in Crude.	Crude.	Épuré.	Total Equivalent in Crude.	
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1897....	19,243	*Nil.*	19,243	298	700	1,343	415	178	682	21,268
1898....	18,160	*Nil.*	18,160	700	258	1,087	404	312	872	20,119
1899....	25,613	345	26,130	275	280	695	.....	100	150	26,975
1900....	34,796	(*b*)	34,796	251	(*b*)	251	197	(*b*)	197	35,244
1901....	31,767	11	31,767	1,704	(*b*)	1,704	1,446	(*b*)	1,446	34,917

EXPORTS OF PITCH-LAKE ASPHALT FROM TRINIDAD. (*a*) (IN TONS OF 2,240 LB.)

Year.	To United States.			To Europe.			To Other Countries.			Grand Total of Exports in Crude Equivalent.
	Crude.	Dried.	Total Equivalent in Crude.	Crude.	Épuré and Dried.	Total Equivalent in Crude.	Crude.	Épuré and Dried.	Total Equivalent in Crude.	
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1897....	71,969	1,769	74,407	14,629	13,510	34,856	.....	500	680	109,943
1898....	46,089	1,692	48,424	15,703	13,228	35,537	698	1,646	2,999	86,960
1899....	70,111	480	70,777	21,337	13,749	41,956	.....	1,699	2,359	115,092
1900....	67,758	3,180	70,938	23,386	16,114	47,352	1,422	2,420	4,453	122,743
1901....	80,449	*Nil.*	80,449	31,213	15,815	54,761	.....	586	844	136,054

(*a*) The exports prior to 1897 will be found in THE MINERAL INDUSTRY, Vol. VII. (*b*) Included in the shipments of crude.

Venezuela.—The right of the Warner Quinlan Syndicate, of Syracuse, N. Y., to operate the asphaltum deposits in the Department of Sucre is still in litigation, and while the Province court at Carupano annulled the concession formerly granted to the New York & Bermudez Co., the matter has been carried on appeal to a higher court. An occurrence of asphaltum has been reported by Mr. R.

Zuber, of London, on the Island of Pedernales, in the Orinoco delta. The deposit is reported to be similar to the asphalt beds of the Island of Trinidad and of an extent to permit an annual extraction of 20,000 tons for some years to come.

OZOKERITE.

In describing the ozokerite industry of Boryslaw, Galicia, F. W. Hossfield states that an attempt has recently been made to form an ozokerite trust which will embrace under one management all the existing mines and mineral leases of mines known or supposed to contain deposits of mineral wax, but owing to the obstinacy of the owners of some smaller tracts, the promoters of the trust have not as yet been successful. The area of the ozokerite beds of Galicia cover 957 sq. miles, and from the latest official report (1898), there were 42 companies engaged in the field, employing 5,413 operatives. The output in that year amounted to 17,068,290 lb. The mineral wax is never found in a pure state, and the material for export is usually freed from earthy matter near the mines. The purifying process is quite simple and consists in placing the material in tanks which are heated either by direct fire or by steam. When direct fired the flames must heat the sides as well as the bottom, otherwise the wax will become overheated and partial distillation will ensue. At the later works steam heat is now used for refining purposes. At first the steam must possess sufficient heat to melt the wax, but when overmelted a much smaller amount only is required to maintain the product. The liquid condition is then continued until the impurities settle to the bottom. The wax is then drained into iron vessels having the form of a cone and previously lime washed to prevent the adherence of the congealed blocks of wax. The blocks weigh from 650 to 850 lb., and are generally from 15 to 25 in. high, with a maximum diameter of from 30 to 36 in. An analysis of the better quality of unadulterated Boryslaw ozokerite gave: Water, 0·33%; naphtha, 5·67%; petroleum, 3·67%; crystallizable paraffine, 82·33%; other substances, residue and loss, 8%. Ozokerite melts between 136°F. and 212°F. Blocks of the latter high degree of fusibility, however, are seldom found. The average melting point of the better qualities is from 140°F. to 158°F. If the wax melts below 136°F. it may be taken for granted that it has been adulterated with other substances. There are about 20 refineries for converting raw ozokerite, and it is doubtful if the processes employed by any two of them are identical. In most of the refining works the wax is mixed with from 6% to 10% of sulphuric acid, heated and filtered through bone charcoal or spodium, which imparts a yellow color to the product. It is again treated with sulphuric acid, and finally with caustic soda, until the acid is completely neutralized. Fairly successful experiments have also been made to avoid the use of sulphuric acid by the substitution of benzol, in which case the solvent must be eliminated by distillation. In the filtering process referred to, coal in small grains is placed between two sieves, which are inserted in each filter. A number of filters are placed together in a frame and sufficiently heated by direct steam to keep the wax in a liquid state. Whenever the coal is tested its efficacy as a bleaching agent is regenerated by a special treatment. After the mass has been decolorized it is

decanted into funnels having paper filters with a device for keeping the material heated during filtration.

In 1900 Austria exported 11,363,779 lb. crude ozokerite, valued at $1,047,805, of which 8,326,333 lb. was shipped to Germany and 22,707 lb. to the United States. This amount, however, does not represent the total quantity shipped to the United States, as much of the product exported to Germany is again re-shipped to this country.

Exports of refined ozokerite or ceresin from Austria in 1900 amounted to 1,927,809 lb. ($234,546) of which 308,864 lb. ($36,261) were shipped to Germany, the direct exports to the United States being 77,381 lb. ($3,085).

Among the new uses to which ozokerite is applied, beyond those enumerated in the preceding volumes of THE MINERAL INDUSTRY, may be mentioned in the manufacture of phonographic cylinders and in galvano plastic printing.

THE HISTORY OF THE ASPHALT INDUSTRY TO 1901, INCLUSIVE.

BY A. W. DOW.

ASPHALT paving in this country may be said to date from the year 1870, although there were a few pieces laid before this date.

The first regular asphalt pavements in Europe were laid with a limestone rock asphalt mined at Val de Travers, Neufchatel, Switzerland, in 1856, on the Rue Bergere, Paris, by M. Vaudry; another small piece was laid in 1858 in front of the Palais Royal, on the Rue St. Honore, one of the most traveled streets in the world, and the first asphalt pavement in the city of London was laid with Val de Travers asphalt on Threadneedle street, near Finch lane, in May, 1869.

The success of these pavements in Europe attracted considerable attention in this country, but the great expense of shipping and laying the European asphalts prevented their use excepting in one or two experimental pieces. Attempts, however, were made to use coal tar mixed with mineral ingredients, and in 1867 a small portion of one of the drives in Prospect Park, Brooklyn, N. Y., was laid with a coal-tar pavement patented by Mr. Scrimshaw, followed by a similar one laid on Diamond street, near Lenox Road, Flatbush, L. I. The latter pavement lasted for more than 20 years. In the city of Washington in the early seventies several patented coal-tar pavements were laid, the great majority of which were utter failures, while some few have given and are still giving excellent service at the present date. With the paucity of knowledge of the construction and the materials used in such paving at that time, it is little wonder that there were so many failures, and it can be considered merely accidental that any of these first still remain.

In 1870 Edward J. DeSmedt procured patents for the manufacture of pavement, using Trinidad asphalt softened by heavy petroleum oil and mixed with sand and powdered carbonate of lime. Samples of this new pavement which were laid in front of the City Hall in Newark, N. J., and around his works in Jersey City, proved so satisfactory that in the next five years the American Asphalt Paving Co., The Grahamite Asphalt Co., The Grahamite Asphalt Paving

Co., and The Grahamite & Trinidad Asphalt Paving Co. were organized. The most notable successes of these various companies were the pavements laid in 1873, on Fifth avenue, between 24th and 25th streets, and in Trimble place, from Duane to Thomas streets, in the city of New York, and in front of Independence Hall, opposite the Ledger Building, in the city of Philadelphia.

The first foreign rock asphalt laid in this country was a small piece of pavement laid with Neufchatel rock asphalt in 1872, on Union Square, New York. The Neufchatel rock asphalt was also used later in several other cities to a limited extent.

In 1876 a special commission was appointed by Congress to decide on the best pavement to be used on Pennsylvania avenue, from the Capitol to the Treasury, in the city of Washington, which decided to pave from Sixth street to the Treasury with Grahamite & Trinidad pavement, laid under the supervision of the patentee, E. J. DeSmedt, using asphalt from deposits on the Island of Trinidad, and between the Capitol and Sixth street with foreign asphalt rock by the North American Neufchatel Asphalt Co.

Before the use of Trinidad asphalt for pavements it had been mined for various purposes. The tenth Earl of Dundonald seems to have first brought Trinidad asphalt into commercial notice. In 1851 he leased for 20 years a large part of the lake and some of the adjoining asphalt land, and in 1865 assigned his lease to a joint stock company called The Trinidad Petroleum Co., Ltd., organized with a view to distilling petroleum out of the asphalt. This company, which seemed not to have been prosperous, went into liquidation in 1866. Mr. Thomas A. Finlayson succeeded to its leasehold rights and continued shipping asphalt.

In the meantime other parties commenced shipping asphalt mined from deposits existing at La Brea and Point d'Ore, Trinidad. In 1871 the Governor decided to lease the asphalt lake in lots of only five acres each, when the existing leases thereon had terminated, with the result that the entire asphalt lake, with the exception of one five-acre lot, came under the control of four lessees. These lessees in time combined so as to monopolize the output of asphalt from the lake, but they still had considerable competition from parties mining asphalt in the village lots of La Brea and at Point d'Ore.

In 1878, Mr. A. L. Barber contracted with Mr. John G. Douglas, who mined asphalt at Point d'Ore, to supply him with asphalt for four years, and in 1880 visited the Island of Trinidad and succeeded in uniting all the conflicting interests connected with the shipping of asphalts, both from the lake and land deposits. But in 1886, when the Colonial Government decided to grant pitch-digging licenses indiscriminately on the five-acre lot formerly held in reserve, which could furnish as much pitch as the remainder of the lake, it is no surprise that the parties in this combination became dissatisfied, for by this procedure the lessees would be forced to do business without protection. It was again through Mr. A. L. Barber that a new contract was made with the Government carrying the exclusive right to mine asphalt from the lake and the protection of the Crown against competition from the other Crown deposits. This new deed was made in July, 1888, between the Crown, and Previte & Creig, of London, and the New York & Trinidad Asphalt Co., of New York, the latter having the exclusive right

for this country. In 1899 the licenses and privileges of the two above companies were assigned to the Trinidad Asphalt Co. This new company, although having a monopoly of the Trinidad Lake asphalt in this country, had a little competition from a few parties mining asphalt in the village of La Brea, among which were the West Indies Asphalt Co., Carter, Hawley & Co., and Christale & Co.

The Trinidad Asphalt Co. gradually acquired these out-lying deposits, until there only remains the original Dundonald holding in the village of La Brea, which is now being worked by the Warner Quinlan Asphalt Co., of Syracuse, N. Y.

In 1880 asphalt was mined in Cuba by W. S. Wilkinson, of Baltimore, Md., and Cranford & Filbert, of Washington and Philadelphia, the former manufacturing asphalt block, which proved of such poor quality that the mining was discontinued in about a year. Cranford & Filbert used it for sheet asphalt, but for various causes only one cargo of this asphalt was imported by them, and later they made a contract with the Trinidad Asphalt Co. for a supply of Trinidad Lake asphalt. The mining of asphalt in Cuba for paving was discontinued until 1901, when the mine at Bajucal, Cuba, which had been purchased by the West Indies Co., of New York, shipped asphalt for fluxing with heavy refined maltha from California into a paving cement which has been laid during the past year in the city of Washington.

Although as stated before a little paving had been done in this country with the foreign rock asphalts, yet no particular company ever did any considerable paving with these materials.

The Sicilian Asphalt Co., of New York, did some paving with a mixture of asphalt rock mined at Regusa, Sicily, and German rock asphalt, but about 1890 it entered into an agreement by which it obtained and laid Trinidad asphalt, and it is now using Trinidad asphalt in all its work. The German rock asphalt, from Limmer, near Hanover, has been used to a considerable extent in this country mixed with other rock asphalts. The asphalt rock mined at Seyssel, Department of L'Ain, France, has been laid more extensively of late than any other foreign rock asphalt by the Compagnie Generale des Asphaltes de France.

The first asphalt rock mined in this country for paving was probably that from Santa Cruz, Cal., which is there called bituminous sandstone, and was first laid in the city of Santa Cruz, in 1868, over an old wooden pavement, but was not extensively used until 1880, when several pavements were laid in San Francisco. At the present time there are several miles of this pavement in San Francisco and other cities on the Pacific slope. Other most important asphalt rocks of California are mined in San Luis Obispo County and Santa Barbara County, but the use of these asphalt rocks, owing to the expense of transportation, is confined to the cities within easy distance of the mines.

The first pavement laid with asphalt rock mined in Breckenridge County, Ky., was in the year 1890, in the city of Louisville. Since then a few miles of pavements have been laid with mixtures of this asphalt with other harder asphalt rocks richer in bitumen. The greater part of the paving done with Kentucky rock has been in the city of Buffalo, where it was laid mixed with Vorwhole asphalt rock from Germany. Other deposits of asphalt sandstone have been

opened up in Kentucky, the most important of which are at Youngs Ferry, Logan County, and at Russellville, Warren County. A little paving has been done with these rock asphalts in cities easy of access to the mines. During 1901 some of the asphalt mine interests of Kentucky have been consolidated into the Federal Asphalt Co.

In 1891 a deposit of asphalt limestone was opened up at Clein, Uvalde, Texas, by the Litho-Carbon Co., which intended to extract the bitumen from the rock and treat it by a patented process until it resembled vulcanized rubber in consistency. This company was not at all successful, and in 1896 went into the hands of a receiver. In 1898 the Uvalde Asphalt Co. secured the mine at Clein, and commenced mining asphalt for paving purposes; some few streets were laid with it, but the expense of transportation limited its use. In 1899 the company installed a plant for extracting bitumen from this rock by means of naphtha, and it is supposed did some little paving, but the process proved so expensive that it was abandoned, and for the past three years the Uvalde Co. has been using asphalt secured from the Trinidad Asphalt Co. During the past year the Uvalde Co. has secured a deposit of asphalt on Lake Maracaibo, in Venezuela, where it has put up an extensive refinery, and expects soon to begin shipping asphalt to this country.

Some paving has been done in St. Louis and other Western cities with asphalt rock from Indian Territory. In the Buckhorn district, about six miles from Dougherty, the most extensive deposits of the Territory are controlled by the Gilson Asphaltum Co., of St. Louis, Mo., which mines both sandstone and limestone impregnated with asphalt, mixing these rocks about half and half for paving.

About 1890 the California Petroleum & Asphalt Co. was organized in California, to mine a hard asphalt at La Patera, Ventura County, and as a flux it extracted a thick maltha from the bituminous sand at the La Conchas mine, at Carpentera. This combination was called Alcatraz asphalt, which name was afterward adopted by the California Petroleum & Asphalt Co. The Alcatraz Asphalt Co. came East with its material about the year 1893 and commenced a strong competition with Trinidad asphalt. It was not long before the mine at Carpentera was exhausted and the La Patera mine was worked to such a depth that it became expensive mining, when the Alcatraz Co. procured its asphalt by evaporating the asphaltic petroleums of California until they were of the consistency of asphalt, to which it gave the name of Grade "D" asphalt. This was not entirely satisfactory, so it attempted the extraction of asphalt from the asphalt sandstone found on the Sisquoc ranch, Santa Barbara County, Cal. The asphalt in a naphtha solution was conveyed by pipe line to the coast, where the naphtha was evaporated and returned to the refinery. This process in turn proved so expensive that it was soon abandoned, and it is said that the company now gets its asphalt from the Harris mine, Santa Maria, Cal. In 1899 the Alcatraz Co. was absorbed by the Asphalt Co. of America, and of late it has done little or no paving excepting on the Pacific coast.

About the time that the California Petroleum & Asphalt Co. was developing its Alcatraz asphalt a company was organized in Kern County, Cal., which mined,

at Asphalto, about 20 miles from Bakersfield, Kern County, an asphalt which is quite hard, and which was fluxed with a heavy maltha obtained from wells in the neighborhood of the mine. This new company, the Standard Asphalt Co., of California, in the year 1894 began introducing its material in the East in competition with the Trinidad asphalt interests, which was continued until it was bought in by the Trinidad interests about the year 1897.

In 1892 Mr. Thomas H. Thomas, of New York, obtained a grant of land from a Mr. Hamilton, for mining asphalt on a concession which the latter had obtained from the Venezuelan Government. This deposit, which is situated at Guanoco, Province of Bermudez, is generally known on the market as the Bermudez asphalt. Mr. Thomas organized the New York & Bermudez Co., and commenced the laying of pavement with this asphalt fluxed with petroleum residuum, under the supervision of Mr. E. J. DeSmedt, and so successfully competed with the Trinidad Lake interests that it was bought up by the Barber Asphalt Paving Co., in 1896.

The mining of asphalt from the Bermudez deposit was carried on by the New York & Bermudez Co. without opposition until 1900, when a portion of this deposit, which is known as the Felecidad, was sold by the Venezuelan Government to Mr. Sullivan, of the Warner Quinlan Asphalt Co. Through this transaction arose the dispute so much discussed of late between the New York & Bermudez Co., or, in other words, the Asphalt Trust, and the Warner Quinlan Asphalt Co. This dispute is still before the courts of Venezuela.

A deposit of asphalt was developed at Tuxpan, Mexico, by the Mexican Asphalt Co., of Chicago, in the year 1896, which did some little paving with it in Chicago. A refinery and paving plant was built in Jersey City, N. J., by this company for the handling of its asphalt, but it is doubtful whether any of it was laid from this plant, and it is generally understood that Trinidad asphalt has been used. In 1900 this company was bought in by the National Asphalt Co.

For over ten years gilsonite, a pure, hard asphalt, has been mined in Uinta County, Utah, for various purposes, but it was not until the year 1898 that the Gilson Asphaltum Co., of St. Louis, Mo., commenced its use for paving. This asphalt was fluxed with heavy California maltha until of a proper consistency for a paving cement known on the market as Buena Vista asphalt. Pavements have been laid with this material in St. Louis and other Western cities. The Gilson Asphaltum Co. was bought in by the Asphalt Co. of America in 1899. Shortly before the introduction of the above asphalt for paving by the Gilson Asphaltum Co., the Assyrian Asphalt Co., of Chicago, commenced its use by fluxing it with Eastern petroleum residuum, and in some cases it has fluxed it with a flux manufactured under the Culmer patent by blowing air into petroleum residuum. The pavements made of this material did not prove all that could be desired, and I believe that it has discontinued the use of this asphalt.

Beside the natural asphalts, there have been used for paving artificial asphalts manufactured from oils. About the first manufactured asphalt on the market was known as Pittsburg flux, which was made by a process patented by Mr. J. A. Dubbs, in 1892, by heating Eastern petroleum residuum with sulphur at a high

temperature. The product obtained resembled a wax more than an asphalt, and with the exception of one street, laid in Pittsburg, it was never used by itself for paving. It was bought a few years later by the Barber Asphalt Paving Co., and used as a flux which gave a desirable property to the resulting asphalt cement when mixed with Trinidad asphalt.

In the year 1894 Mr. F. X. Byerley, of Cleveland, Ohio, procured a patent for the manufacture of an artificial asphalt from petroleum by the oxidation of petroleum residuum by blowing air into it while heated at a high temperature. The material resulting from this process was a poor imitation of asphalt, and, although some few pavements were laid with it, they have not proved of desirable quality. About 1896 Mr. J. A. Dubbs applied his process of heating oils with sulphur to the California asphalt oils and commenced the manufacture of an artificial asphalt under the trade name of Ventura Brand California Asphaltum. The California Asphaltum Co. manufactured this product at its refinery at Ventura, Ventura County, Cal. Considerable of this asphalt was used throughout the country, principally in Pittsburg and Allegheny. In 1899 this company and its patent were bought out by the Asphalt Co. of America.

The Los Angeles Oil Burning & Supply Co. erected a refinery in Los Angeles, Cal., for the manufacture of asphalt from the oils of that neighborhood by simply distilling off the light oils. This company reorganized in 1896 under the name of the Western Oil & Asphalt Co., and continued the manufacture of asphalt under this name until it was bought out by the Asphalt Co. of America in 1899. The president of the Western Oil & Asphalt Co. soon after this organized a new company which is now manufacturing asphalt from oil in Los Angeles, under the name of the Southern Refining Co.

The Union Oil Co., of California, has been manufacturing from oil an asphalt for paving which it calls Diamond Asphalt.

Of late there have been several companies organized for the manufacture of asphalt from California oils, among which may be named, Jewett & Blodgett, the Pacific Refining Co., of Bakersfield, Cal., and the Ojai Asphalt Co., of Santa Paula, Ventura County, Cal.

The Present Condition of the Asphalt Paving Industry.

The most important company at the present time is the National Asphalt Co., or what is popularly known as the Asphalt Trust, which was organized in 1900 by John C. Mack, of Philadelphia, and first consisted of the Mexican Asphalt Co., of Jersey City, the Hudson River Stone Co., and several minor companies controlled by Mr. Mack. Shortly after its organization it absorbed the Asphalt Co. of America, which was then known as the Asphalt Trust. The principal companies composing the Asphalt Co. of America were the Barber Asphalt Paving Co., Warren Scharf Asphalt Co., New York & Bermudez Asphalt Co., the Alcatraz Asphalt Co., the Gilson Asphaltum Co., Standard Asphalt Co. of California, the Trinidad Asphalt Refining Co., and the Columbia Construction Co. Among the other important companies beyond the control of the National Asphalt Co. are the Warner Quinlan Asphalt Co., of Syracuse, N. Y., using asphalt mined from

the Dundonald Estate on the Island of Trinidad. This company is supplying several companies with asphalt. The Globe Asphalt Co., having its refinery at Obispo, Cal., is supplying companies throughout the country with asphalt. Its Eastern agent is the Inter-State Paving Co. The Warren Asphalt Co., of Utica, N. Y., is suppling Warren's Acme California Asphalt, manufactured in Los Angeles, Cal. The Southern Refining Co., of Los Angeles, Cal., is supplying Southern Cross Asphalt, manufactured in Los Angeles, Cal., and the West Indies Co. is furnishing Cuban asphalt fluxed with Californian maltha. There are several other companies supplying both asphalt and asphalt rock.

The asphalt block industry, with a few minor exceptions, obtained its supply of asphalt from the International Paving Co., which, by a special contract made by its president at the time of the formation of the Trinidad Asphalt Co., buys Trinidad Lake asphalt from the latter company.

During the past year a new patented pavement has been brought out by the Warren Brothers Co., of Boston, Mass., which is known as bituminous macadam, and is made by binding together stone graded from about 1·5 in. in size to an impalpable dust, with a specially prepared bitumen manufactured from coal tar. Several pavements of the above class have been laid throughout the country during the past year.

BARYTES.

THE production of barytes in the United States during 1901 amounted to 49,070 short tons, valued at $157,844, as compared with 41,466 short tons valued at $194,178, in 1900, showing an increase of 7,504 short tons. As in recent years the supply was obtained from Missouri, Virginia, Tennessee, North Carolina and Georgia in the order of their production. The mineral is mined chiefly in open cut as shaft sinking is too costly at the present price of the product. Barytes occurs in many other States, notably Arkansas, Connecticut, Delaware and Kentucky, but no output was obtained from these deposits during 1901. In some instances, however, a small amount of development work has been accomplished.

The following tables give the production, imports and consumption of barytes in the United States from 1897 to 1901 and the world's output for the years 1896 to 1900, inclusive.

PRODUCTION, IMPORTS, AND CONSUMPTION OF BARYTES IN THE UNITED STATES.

(In tons of 2,000 lb.)

Year.	Production.			Imports.			Consumption.	
	Quantity.	Value Per Ton.	Value.	Quantity.	Value Per Ton.	Value.	Quantity.	Value.
1897.....	26,430	$4·00	$105,720	2,018	$7·14	$14,401	28,448	$120,121
1898.....	28,247	4·00	112,988	1,914	5·93	11,856	30,161	124,344
1899.....	32,636	4·20	137,071	4,312	6·59	28,407	36,948	165,478
1900.....	41,466	3·90	161,717	5,625	5·77	32,461	47,091	194,178
1901.....	49,070	3·22	157,844	5,604	7·04	39,442	54,674	197,286

PRODUCTION OF BARYTES IN THE PRINCIPAL COUNTRIES. (*a*) (IN METRIC TONS.)

Year.	Belgium.	Canada.	France.	Germany.				United Kingdom.	United States.
				Baden.	Bavaria.	Prussia. (*c*)	Saxony.		
1896....	25,000	181	2,791	130	3,397	38,438	574	24,117	21,900
1897....	23,000	518	3,209	400	3,365	36,394	218	23,087	26,430
1898....	21,700	971	2,763	1,100	4,339	48,082	478	21,514	28,247
1899....	25,900	1,207	4,058	2,430	6,214	52,920	216	25,059	29,607
1900....	38,800	1,213	3,635	2,970	10,515	60,099	516	29,937	37,618
1901....	(*h*)	653	(*h*)	(*h*)	(*h*)	(*h*)	(*h*)	25,050	44,516

(*a*) From official reports of the respective countries, except the statistics for the United States. (*b*) Not reported. (*c*) Output of the mining districts of Clausthal and Bonn. (*h*) Statistics not yet available.

Missouri.—The largest individual production of barytes by States during 1901 was derived from Missouri, where the mines, principally in Washington County, are of very great extent. The great bulk of the shipments is made from Mineral Point, Cadet and Potosi, via the St. Louis, Iron Mountain & Southern Railway.

Tennessee.—(By C. S. Herzig.)—The barytes deposits of East Tennessee may be divided into veins and boulders, the former occurring along the Western North Carolina branch of the Southern Railway, around the State line, both east of it in North Carolina and west of it in Tennessee, and the latter around

Sweetwater, about 40 miles west of Knoxville. The strike of both deposits is east of north. The veins occur usually with a quartzite hanging wall and sometimes with a quartzite foot-wall, generally accompanied by a low-grade clayey iron oxide locally called umber, which underlies and at times surrounds the ore itself, making the mining cheap and the ore easily obtained, so that an 8-in. to 10-in. seam of barytes can be worked at a profit. These veins are from 6 to 8 ft. wide and of considerable length; usually the width of the workable veins is from 2 to 4 ft. Due to line of fracture the ore bodies break out in irregular conchoidal blocks. In mining the underlying umber is removed and the ore broken down by hand picks in lumps of from 25 to 100 lb. weight. The barytes is separated from the refuse material, removed to the surface, where it is stacked and dried, and again cleaned before shipment. The principal vein mines, near Myers and Wolf Creek, Tenn., and at Hot Springs, N. C., are owned or controlled for the most part by John T. Williams & Sons, of Knoxville. This concern is building a large mill to grind the ore and manufacture the commercial products.

The boulder deposits at Sweetwater have been operated for many years with indifferent financial success. Large quantities of barytes occur in the residual clay which has resulted from the weathering of the calcareous formation prevailing in that portion of Tennessee. These deposits have a general direction east of north, and in most cases the ore crops out at the surface. The exploitation of these deposits has so far been confined to shallow surface workings, but further development will doubtless show that the ore now found in boulder form embedded in the clay is derived from veins similar to those found near the North Carolina line. It appears that the veins occurred originally in the limestone and due to weathering action, the soluble portions of the limestone were dissolved and washed away, leaving the barytes in its original form and the insoluble iron oxides to color the residual clay. The ore zone is often several hundred feet wide, so that some of the lumps must have been moved a considerable distance from the place where they were originally broken down. The character of the lumps, which vary in size and weight up to 100 lb., is identical with the material mined in the vein deposits. The barytes is usually of good grade, although a small amount of impure ferruginous material is found. The boulder deposits have been mined in a primitive manner by shallow surface pits that have been abandoned as soon as the excavation became too deep for the easy removal of the material. On account of the crudity of the work the cost has been greater than the return. The application of proper mining principles and the control of a mill to convert the crude material into the finished product are two factors which will aid to place operations on a profitable basis. The production of barytes in Tennessee during 1901 was probably less than 15,000 long tons, 70% of which was obtained from the Sweetwater district.

The Hiawassee Mining Co., of Knoxville, which operated extensively in 1900, was declared insolvent during 1901 and was placed in receivers' hands.

The price of crystalline ore of the eastern part of the State varied from $1·50 to $4 per ton, according to quality, while the flake variety from the Sweetwater district brought $3·50 per ton, all f. o. b. cars.

Virginia.—The Tri-State Mining Co., of Pittsburg, Pa., is completing a 50-ton plant at Richlands, Tazewell County, to grind the barytes from its mines. The firm of Dingee & Weinman, of Lynchburg, Va., one of the largest operators in the South, has been succeeded by Mepham & Krause Co. At Evington, the Hewitt mines, one of the oldest operative mines in the States, continued its shipment of barytes to Lynchburg.

Market.—Consumption in 1901 was good and prices ruled steady. New sellers of the domestic product have appeared, causing closer competition, with the result that some of the larger Virginia and Missouri mines are planning a consolidation which is likely to materialize early in 1902. New York quotations were: Crude, No. 1 domestic, $9 per short ton; No. 2, $8; No. 3, $7·75; for wholesale quantities. German barytes, gray in color, were $14·50 per ton, and white, $17·50. Blanc fixe (artificial barium sulphate) was in good request, selling at 1@2c. per pound, according to quantity and quality.

TECHNOLOGY.

Barium Oxide.—The Bradley & Jacobs process (German Patent No. 111,667, December 16, 1898) for the preparation of barium oxide in the electric furnace, which is operated at Niagara Falls, N. Y., by the United Barium Co., consists in treating an intimate mixture of 137 parts of pure barytes and from 7 to 12 parts carbon in the electric furnace, which transforms the barium sulphate into barium sulphide according to the reaction: $4BaSO_4+4C=BaS+4CO+3BaSO_4$. At the high temperature of the electric furnace, barium has a greater affinity for oxygen than for sulphur. A second reaction takes place in which the barium sulphide reduces the sulphate not yet decomposed and forms barium oxide and sulphur dioxide gas as follows: $3BaSO_4+BaS=4BaO+4SO_2$. These reactions are not independent, but occur simultaneously, and as the reduction due to the carbon is much more rapid than that caused by the action of the sulphide there is always an excess of barium sulphide. In practice about 60% barium oxide and about 40% barium sulphate are obtained, the residual undecomposed sulphate amounting to less than 1%. The addition of barytes when the reaction has been under way for some time aids in the production of barium oxide. The resultant mixture is treated with hot water and barium hydrate obtained, which can be subsequently crystallized as $BaOH_2.8H_2O$ from the concentrated solution. The furnaces employed are operated continuously and have a maximum power consumption of 500 K.W. and a maximum output of 8 tons of product per 24 hours. The crystals of barium hydrate containing less than 1% impurity, after a thorough washing with cold water and drying, are melted and run into thin iron drums of 500 lb. capacity. The efficiency of this process extracts from 97 to 98% of the barium sulphate in the crude mineral and at the relatively low cost of treatment it can produce barium salts at a price which will doubtless result in a great increase in their consumption. Although in operation less than a year, the capacity of the plant has been increased to 60 tons per day. Hitherto barium hydrate has been consumed chiefly by the beet sugar industry to remove the sugar from molasses. Steps are being taken to utilize, for the manufacture

of sulphuric acid, the sulphurous gas which is evolved during the smelting of barytes, which would make the process well rounded.

Barium Dioxide.—The production of hydrogen dioxide from barium dioxide in France during 1899 amounted to 5,800 tons, which was used to manufacture oxygenated water; 11 works in France are engaged in the manufacture of oxygenated water, 4 of these making the barium peroxide as well. Oxygenated water is used extensively in bleaching linen, silk, straw, feathers, coral ivory. It is also used as an antiseptic and as a cosmetic in bleaching the hair. The present world's production of barium dioxide is estimated at 10,000 long tons annually.

Lithophone.—This valuable pigment consists essentially of a mixture of barytes with zinc oxide and zinc sulphate in varying proportions. The best quality contains from 65 to 70% $BaSO_4$, 12 to 15% ZnS and 10 to 13% ZnO. Details of the manufacture of lithophone are given under the caption "Zinc and Cadmium," later on in this volume.

Review of Analytical Chemistry.—(By Edmund H. Miller.)—C. H. Peters[1] investigated the precipitation of barium, strontium, and calcium as oxalates, and their subsequent determination by indirect titration with potassium permanganate. In order to get sufficiently complete precipitation of strontium oxalate, the volume of the solution should be 100 c.c., and should contain one-fifth 85% alcohol, as this oxalate is soluble in 12,000 parts of water. For barium oxalate, which is soluble in 2,590 parts of water, one-third of the solution should be alcohol. The conditions for precipitation are as follows: To the barium solution 100 c.c. in volume and containing about 30% alcohol, add an excess of ammonium oxalate and allow to stand over night; filter on asbestos in a Gooch crucible, wash with water containing 30% alcohol and dry over a flame to expel the alcohol, which would reduce permanganate. The crucible with the precipitate is put in a large beaker, with from 100 to 200 c.c. of water, from 5 to 10 c.c. concentrated hydrochloric acid, and from 0·5 to 1 g. of manganous chloride, and the resulting solution titrated by permanganate at a temperature of from 35 to 40°C. The results given are quite satisfactory, and better than when sulphuric acid is used, as the barium sulphate retains oxalic acid by occlusion. In regard to the precipitation of these oxalates when used as a means of separation from magnesium, the recent article by Prof. Richards[2] affords very valuable information.

E. Groschuff[3] gives the solubility of the different hydrates of barium oxalate and also of the acid oxalate $BaC_2O_4,H_2C_2O_4,2H_2O$.

D. Vitali[4] describes a method for the recognition of barium compounds in the contents of the stomach to be used in cases of poisoning.

L. Dobbin[5] calls attention to the very considerable solubility of barium sulphate in solutions of sodium thiosulphate ("hypo"), and suggests this as another source of error in the difficult determination of mixtures of sulphates, sulphites, thiosulphates, etc.

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[1] *American Journal of Science*, September, 1901, pp. 210-224.
[2] *Zeitschrift fuer Anorganische Chemie*, 1901, p. 71.
[3] *Berichte*, Vol. XXXIV., p. 3313.
[4] *L'Orosi*, Vol. XXIII., p. 260.
[5] *Journal of the Society of Chemical Industry*, March 30, 1901, p. 218.

BISMUTH.

THE supply of bismuth ores in the United States continues to be obtained from Colorado, and in 1901 the production amounted to 318·6 short tons, as compared with 220 short tons in 1900. Lake County contributed 253·6 short tons of ore of from 4 to 10% Bi, while Ouray County produced 65 short tons of ore, which varied from 6 to 12% bismuth content. The ore contained gold and silver, for which the producers were paid. The price paid for bismuth ranged from $2 to $11 per unit. Owing to the limited demand for the metal the producers of ore are disinclined to report their production and the details of market conditions. As nearly as can be ascertained the output of 318·6 short tons was valued at $25,488, less transportation and treatment charges, or an average of $80 per ton. In recent years practically the entire output was purchased by the Leadville Sampler, at Leadville, the State Ore Sampling Works, at Denver, or was shipped direct to Johnson, Matthey & Co., Ltd., England. During 1901, however, a considerable portion was diverted to other buyers.

The world's supply of metallic bismuth is controlled by the combined interests of Johnson, Matthey & Co., Ltd., and the Saxon Government, who regulate absolutely the production and prices of the metal and its ores. The supply of this metal greatly exceeds the demand and necessitated a combination of interests in order to maintain the price at a figure which would be remunerative to mine owners. The schedule of prices for ore during 1901 showed no change from the previous year. The price is based on the market price of metal, and with the latter at $1·25 a lb. the following rates were paid on delivery at the smelting works, all deductions for treatment having been made: 10% ore, $150 per ton; 15% ore, $200 per ton; 20% ore, $350 per ton; 30% ore, $550 per ton; 40% ore, $750 per ton, 50% ore, $1,000 per ton.

The price for refined metallic bismuth ranged from $2·25 per lb. in January-March to $2·05 in April-June; $2·025 in July and August; $1·64 in September to the closing quotation of $1·50 in October-December. The drop in price was due to the purchase of ore by buyers outside of the so-called "Bismuth Association."

While bismuth occurs both in the combined and free state in many of the Western States the mining of its ores is limited to Colorado. The principal

minerals in the State are: the carbonate, which occurs in Lake, Larimer, Boulder and Chaffee counties; native bismuth in Summit, Jefferson, Boulder and Larimer counties; tellurate and telluride in Boulder and Ouray counties; sulphobismuthite in Park, Custer, Ouray, Hinsdale, Clear Creek, La Plata, Boulder, San Juan and Lake counties.

The importation of bismuth ore in the United States was 165,182 lb. valued at $239,906, against 180,433 lb. valued at $246,597, in 1900. In addition to this there was a small importation of bismuth compounds in medicinal preparations.

Review of Analytical Chemistry.—(By Edmund H. Miller.)—Three new methods for the estimation of bismuth have appeared during the past year:—

(1) Warwick and Kyle[1] describe, with a few additional details Patterson Muir's method, as given by Sutton,[2] of which the following is an abstract: 1 g. of finely ground ore is treated with from 5 to 10 c.c. of concentrated nitric acid, and evaporated to dryness on a hot plate, but not baked; 5 c.c. of nitric acid are added, and the residue broken up; then 25 c.c. of water, and the whole transferred to a beaker and diluted to 100 c.c. with hot water. The insoluble residue is not filtered out, but the bismuth is precipitated in the solution containing 5% nitric acid by an excess (5 g.) of ammonium oxalate or[3] oxalic acid; not potassium oxalate, as used in a later method by Muir and Robb, as it gives an insoluble double salt, $Bi_2(C_2O_4)_3,K_2C_2O_4$: boil vigorously for five minutes; allow to cool and settle; decant the clear solution through a filter, leaving the precipitate in the beaker. The precipitate is boiled with two successive portions of water (about 50 c.c. each), and filtered through the filter already used. This treatment converts the bismuth to a basic oxalate, and is sufficient for ores containing about 10%; if richer, re-treat till the filtrate is neutral (showing that all the oxalic acid is removed, except that combined with the bismuth as a double salt). The precipitate of basic bismuth oxalate is washed down to the point of the funnel and dissolved through into the beaker containing the rest of the precipitate by a little hydrochloric acid (1 to 1), warmed till solution is complete (from 2 to 5 c.c. of hydrochloric acid being required), and diluted to 250 c.c. with hot water; then neutralized by ammonia and reacidified by dilute sulphuric acid. The oxalic acid so liberated is titrated at 70 to 100°C. by standard permanganate as usual. The authors state that as regards permanganate, 10 mg. iron are equivalent to 18·68 mg. of bismuth; this corresponds to one molecule of oxalic acid for each atom of bismuth, as given by Muir. According to this last-named authority, if other metals are present which give insoluble oxalates, the bismuth must be first separated as oxychloride. Warwick and Kyle state that this is unnecessary, and claim that the method is accurate to within about 0·1%, even in the presence of large amounts of copper. This is in direct contradiction to the recent work of Peters[4] on the precipitation of copper by oxalic acid, and to the experience of C. A. Grabill[5] in testing the method. The explanation of this difference of opinion lies

[1] *Engineering and Mining Journal*, April 13, 1901.
[2] *Volumetric Analysis*, Eighth Edition, p. 174.
[3] See later.
[4] *Zeitschrift fuer Anorganische Chemie*, 26, 111, 1901; also, *American Journal of Science*, No. 59; *Chemical News*, 83, May 10, 1901, 221 *et seq.*
[5] *Engineering and Mining Journal*, Sept. 20, 1901.

partly in the different behavior of ammonium oxalate and of oxalic acid. Copper oxalate is readily soluble in the first, but not in the latter. (Method not recommended.)

(2) G. Frerichs[6] employs the reaction of bismuth sulphide on silver nitrate for the determination of bismuth in surgical dressings, etc. The freshly precipitated sulphide is shaken vigorously with a measured excess of N/10 silver nitrate solution and 10 c.c. of nitric acid, made up to 100 c.c., and the excess of silver in 50 c.c. found by Volhard's method, titration with ammonium sulphocyanide using ferric alum as indicator. The essential reaction is the formation of silver sulphide and bismuth nitrate; 1 c.c. N/10 silver nitrate is equivalent to 0·00693 g. of bismuth.

(3) Karl Wimmenauer,[7] after reviewing and repeating the work already done on the electrolytic deposition of bismuth, gives the following conditions as the most satisfactory for its determination: From 0·1 to 0·3 g. of bismuth nitrate is dissolved in from 2 to 4 c.c. of glycerine solution, one part of glycerine to two parts of water, diluted to 150 c.c. and electrolyzed by a current of 2 volts and 0·1 ampere. The temperature is gradually raised to 50°C. and the current density reduced to 0·05 amperes. When the electrolyte was kept agitated, as much as 0·4 g. of bismuth was deposited as a bright dense deposit in three hours. The results given are very satisfactory, especially when an electrode having a rough surface is used.

Prof. Smith in a recent address before the American Chemical Society stated that bismuth could be deposited quantitatively from a solution containing a small quantity of free sulphuric acid. The full details have not yet been published; but the following method has been used with success in Denver:[8] 0·5 g. of bismuth ore is boiled for 10 minutes with 10 c.c. nitric acid, 10 c.c. of sulphuric acid is added and evaporated to white fumes; then taken up with 50 c.c. of water and boiled, and the residue filtered off, cooled, diluted to 125 c.c., and electrolyzed at the ordinary temperature for four hours. The current used was from 3 to 4 volts and from 0·3 to 0·5 ampere per 100 sq. cm. of cathode area.

[6] *Apotheker Zeitung*, 15, 859.
[7] *Zeitschrift fuer Anorganische Chemie*, 27, 1.
[8] Private communication from Prof. E. F. Smith.

BORAX.

THE production of borax in the United States continues to be derived mainly from the colemanite deposits of California, although the marsh deposits of California, Oregon and Nevada contribute a small quota to the total output, which during 1901 amounted to 17,887 short tons of crude borax, valued at $314,811, and 5,344 short tons of refined borax, valued at $697,307, the total value being $1,012,118. Of the total output California produced 16,887 short tons crude borax, valued at $297,198, and 5,344 short tons refined borax, valued at $697,307, the total value of the product from this State being $994,505.

IMPORTS OF BORATES, ETC., INTO THE UNITED STATES.

	1900.			1901.		
	Metric Tons.	Lbs.	Value.	Metric Tons.	Lbs.	Value.
Borax	125·15	273,706	$9,937	247·29	545,045	$20,643
Borates of lime or soda (crude sodium borate and refined sodium borate)	26·44	58,294	5,306	47·05	103,700	9,411
Boric acid	214·67	473,251	17,486	328·95	725,005	26,629

California.—The chief items of interest in the crude borax industry during 1901 were the development and largely increased production of the colemanite deposits of Ventura County and the introduction of new methods and new capital in the working of the low-grade mud deposits near Daggett. The Western Mineral Co. has erected a modern plant and has increased its capacity considerably, its product being a boric acid concentrate, which is shipped East for making borax. Several important chemical difficulties, which have heretofore baffled chemists, have been overcome, and the production of boric acid is now being actively developed.

The Standard Sanitary Co., of Pittsburg, Pa., has absorbed the Columbia Mining & Chemical Co., whose great mud deposits near Daggett and extensive plant in the town are now operated by the American Borax Co. New machinery has been added. The air method of making sulphurous acid has replaced the steam method and the capacity of the plant considerably increased. A railroad has recently been built from the mines to the works, a distance of six miles, and

elaborate arrangements have been made to handle cheaply large quantities of low-grade borate ores. The product, a boric acid concentrate, will be mostly used by the company at its works at Pittsburg, Pa., where it consumes large quantities of boric acid. Careful laboratory work is being done by both companies, and it is worthy of note to record that this is the first determined effort made to work low-grade deposits of calcium borate ores in this country.

The Ventura colemanite mine, owned by the Stauffer Chemical Co., yields upward of 100 tons of high-grade calcium borate per month for manufacture into boric acid at the factories of the company in San Francisco. Considerable development work has been done during the year on this very promising property.

No new borate ore bodies have been discovered of late. The marshes in Nevada and California have been worked to some extent, but the output therefrom is comparatively insignificant in the market.

The Pacific Coast Borax Co., as heretofore, supplies nearly all the borax used in this country and a proportion of the boric acid as well. Its colemanite mines at Borate, 12 miles northeast of Daggett, continue to yield as much ore as the market requires, though the greater depth of mining has increased the cost of extraction. This company controls the borax market in the United States, and has shown wise conservatism in resisting the temptation to increase prices during the recent period of high values. The burning of its large factory at Bayonne, N. J., in April, 1902, has had no effect upon the market, nor even compelled the reopening of the plant at Alameda, Cal. There is no immediate prospect of any decided increase in the production of borate nor change of values.

Oregon.—The marsh deposits of sodium borate in Harvey County have been operated for the past five years and the refineries have produced a yearly output of 400 short tons of refined borax, which is carried by mules to Winnemucca, on the Central Pacific Railway, and thence to Chicago, St. Louis, and occasionally to San Francisco. The deposit extends over 10,000 acres south of Lake Alvord, and with the existing transportation facilities not more than 25% of the area can yield ore of sufficient richness to pay for working. The Rose Valley Borax Co. owns 2,000 acres of the richest portion of the deposit close to the lake. The ground is level and treeless and is incrusted with a layer of sodium borate several inches thick, which contains also sodium carbonate, sodium sulphate, sodium chloride, and other salts in varying proportions. During the long dry summers, the loose surface deposit is shoveled into small heaps and is replaced with a second incrustation within a comparatively short time. No mining is done in winter, and sufficient material is collected in the summer months to furnish the supply to the refining works so that they may operate throughout the entire year. The crude material, containing from 5 to 20% boric acid, is shoveled into tanks filled with boiling water, to which is added chlorine or sulphuric acid to dissolve the alkali salts and free the boric acid. After 24 hours the clear supernatant liquor is drawn off into crystallizing tanks and allowed to cool, forming white pearly scales of high-grade boric acid and a mother liquor which is used repeatedly until it contains a sufficient quantity of sodium salts to warrant a separate treatment.

Market.—There has been but little fluctuation in the price of borax during 1901, the price being from 7 to 7·25c. for the refined article and 6·75 to 7c.

for the concentrated product. The concentrated grade, however, is not of uniform quality and is gradually disappearing from the market.

THE WORLD'S PRODUCTION OF BORATES, ETC. (*a*) (IN METRIC TONS.)

Year.	United States. Calcium Borate.	Chile. Calcium Borate. (*b*)	India. Borax. (*b*)	Germany. Boracite.	Italy. Boric Acid, Crude.	Peru. Calcium Borate. (*b*)	Turkey. Pandermite (*b*)
1896.....	12,310	7,486	340	184	2,616	1,179	12,626
1897.....	17,600	3,168	280	198	2,704	11,850	11,375
1898.....	13,911	7,034	184	280	2,050	7,178	(*h*)
1899.....	21,834	14,951	(*h*)	183	2,674	7,638	(*h*)
1900.....	23,456	13,177	(*h*)	232	2,491	7,080	(*h*)

(*a*) From official reports of the respective countries except the United States. (*b*) Exports. (*c*) Fiscal years. (*d*) Product of refined borax. The manufacture of boric acid was begun in the United States in 1896, in which year there was a production of 621,000 lb. There are no statistics for subsequent years. (*h*) Not reported.

The Borax Consolidated, Ltd., gives a very favorable report for the fiscal year ending September 30, 1901. Net profits for the year were £190,278, from which interim dividends of £22,000 on preferred stock and £30,000 on ordinary stock—£52,000 in all—were paid, leaving £138,278. Adding £13,360 brought forward from previous year, gives a total surplus of £151,638. The mines and deposits continue to yield satisfactory returns, and as a result of the systematic development work a vast quantity of high-grade borate has been blocked out.

Argentina.—The International Borax Co. during 1901 operated the Tres Moros mines; some 500 laborers were employed, and they mined on an average 700 tons per month. The shipments from the Province of Salta to Europe in 1901 exceeded 16,000 tons.

Chile.—Borax and boracite are found principally in the districts of Ascotan and Carcota, Province of Antofagasta, and in the Department of Copiapo, Province of Atacama. The deposits of Ascotan and Carcota were worked for a long time by a Chilean company and are now owned by a California concern. In 1900 these mines produced 13,176 metric tons calcined boracite and 26 metric tons borax. A syndicate has recently purchased a borax property known as the Barateras de San Juan de Diologue, at a stated price of $150,000.

Russia.—Borax is found on the Kertch and Taman peninsulas of southern Russia, where it occurs in connection with mud volcanoes. The mud soon after eruption is encrusted with various salts including borax, soda and salt, which are recovered by dissolving in water and evaporation.

Technology of Borax Manufacture.—The mineral borocalcite, a calcium borate, from Asia Minor furnishes a base for the manufacture of the greater part of the borax consumed in Europe. The crude mineral is treated with caustic soda, which forms borax and calcium carbonate. The best results were obtained by the use of a mixture of caustic soda and sodium bicarbonate; the ore is finely crushed in a mill and 15 parts mineral are placed in a steam-heated boiler with 60 parts water, 8 parts sodium bicarbonate, and 2 parts caustic soda; the whole is boiled for about three hours. The resultant mass is filtered and the hot filtrate crystallized, yields at the end of a few days crystals of borax, which are steam dried. The crystals thus obtained are assorted and barrelled. The cake of calcium carbonate remaining in the filter-press is washed with water until the borax is completely extracted, and is then sold to glass, paper or cement works. It is esti-

mated that 100 lb. of borocalcite will yield from 100 to 105 lb. of crystallized borax.

Review of Analytical Chemistry.—(By Edmund H. Miller.)—E. Polenske[1] states that when borax is distilled with methyl alcohol, from 57 to 59% of the boric acid present passes over in the distillate, about 50% readily, the remainder slowly. Sodium metaborate, $Na_2B_2O_4$, in distillation with methyl alcohol gives off boric acid till the composition becomes $5Na_2O,4B_2O_3$, when the excess of soda prevents the formation of boric esters.

Luhrig[2] confirms the accuracy of the titration method based on the fact that boric acid in the presence of glycerine does not react acid with methyl orange, but does with phenolphtaleïn and can be titrated by alkali using this indicator. Jorgensen's directions were followed. This method is applied to borax by liberating the boric acid by an excess of sulphuric acid then neutralizing this excess by caustic soda, using methyl orange, which leaves the boric acid free, glycerine and phenolphtaleïn are then added, and the boric acid titrated by standard sodium hydroxide.

E. Zschimmer[3] gives the following directions for the analysis of Italian crude boric acid:—

(1) One grain of the air-dried sample is dissolved in 300 c.c. of glycerine and water and titrated with standard barium hydroxide, using phenolphtaleïn as indicator; when the pink color appears more glycerine is added, and if not permanent the titration is continued.

(2) The sulphur trioxide is estimated as usual in 1 g. of sample.

(3) Several mixtures of boric acid and ammonium sulphate of known composition are made and titrated so as to find the number of c.c. which actually correspond to 1 gm. of sulphur trioxide present as ammonium sulphate.

(4) The glycerine is tested for acidity. From the volume of barium by hydroxide used, deduct that required for the sulphur trioxide found to be present and calculate the remainder of boric acid.

Carnielli,[4] after comparing a number of methods for boric acid, gives the preference to Thompson's volumetric method (already described), and mentions favorably the distillation method of Gooch-Rosenblatt. An extensive review of the methods for the determination of boric acid will be found in *Zeitschrift fuer Analytische Chemie,* Vol. XXXIX., p. 465, 1900.

[1] *Zeitschrift fuer Untersuchung der Nahr und Genussmittel*, 1901, IV., 801.
[2] *Ibid.*, 801, 1901.
[3] *Chemiker Zeitung*, Jan. 16, 1901, pp. 44 and 67.
[4] *Gazetta*, 31, 544.

BROMINE.

THE production of bromine in the United States during 1901, including the quantity of bromine contained in potassium bromide, amounted to 552,043 lb., as compared with 521,444 lb. in 1900. The production of bromine in the world continued to be controlled by the associated American producers and by the Leopoldshall-Stassfurt convention, which has several years longer to run.

Michigan.—The production of bromine in potassium bromide during 1901 was equivalent to 163,120 lb., which, with the 54,875 lb. of liquid bromine produced, gives an aggregate of 217,995 lb. The Midland companies still control the bromine situation in the United States, although a small quantity has been made *sub rosa* from the Saginaw bitterns. The Red Cross well at Big Rapids is being fitted up to produce bromine commercially, and a shaft is being sunk for rock salt just south of Detroit. The deposit is large and offers a good field.

PRODUCTION OF BROMINE IN THE UNITED STATES.

Year.	Michigan.	Ohio.	Pennsylvania.	West Virginia.	Total.	Metric Tons.	Value.	
							Total.	Per Pound.
	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.			
1897.....	(a) 147,256	124,972	116,967	97,954	487,149	221	$136,402	28c.
1898.....	(a) 141,232	106,860	119,998	118,888	486,978	221	136,354	28c.
1899.....	(a) 138,272	82,866	111,150	101,213	433,003	196	125,571	29c.
1900.....	(a) 210,400	91,182	105,592	114,270	521,444	237	140,790	27c.
1901.....	(a) 217,995	125,467	101,595	106,986	552,043	250	154,572	28c.

(a) Including the bromine equivalent of the product recovered as potassium bromide.

CALCIUM CARBIDE AND ACETYLENE.

THE progress of the calcium carbide industry depends to a large extent upon the new uses for acetylene gas as well as upon its normal established consumption for industrial purposes. The possessor of a quantity of carbide cannot use it until he has the necessary appliances to convert it into acetylene gas. In spite of their mutual interdependence the manufacture and sale of acetylene apparatus is not necessarily connected with the carbide industry, and in fact, the two industries are operated separately and with separate capital throughout the world.

Toward the end of the year 1901, the acetylene industry showed signs of healthful progress. The apparent ease of bringing calcium carbide and water into contact, and the obvious multiplicity of devices, with which it is possible to accomplish this end, have unfortunately, from the very beginning attracted the attention of those who have possessed but a fair mechanical knowledge, and have not at all understood the chemistry involved in the combustion of inflammable gases. Owing to the small cost of constructing an apparatus, or so-called "generator," in which carbide and water are brought into contact, the field has been attractive to incompetent inventors, with the result that poorly designed and badly constructed machines have been largely introduced. Many instances of dissatisfaction with the use of acetylene gas are recorded which have been due to the annoyances and danger caused by the use of inferior apparatus, but the excellence of the light, *per se,* has fortunately led to the conclusion that the fault lay with the details of the apparatus and not with the gas itself.

Carbon and hydrogen combine to form an almost infinite number of substances in which more hydrogen atoms than atoms of carbon are almost invariably contained. The lowest in the series is acetylene C_2H_2, possessing not only the highest calorific power of all, but also the greatest illuminating power. Without reviewing the chemistry of the manufacture of acetylene, which has already been fully described in previous volumes of THE MINERAL INDUSTRY, the following table of the illuminating power of various hydrocarbons of the $CxHx$ series is of interest:—

Name.	Formula.	Candle Power.	Name.	Formula.	Candle Power.
Methane	CH_4	5·2	Ethylene	C_2H_4	70·0
Ethane	C_2H_6	37·7	Butylene	C_4H_8	123·0
Propane	C_3H_8	56·7	Acetylene	C_2H_2	240·0

In the light of our present knowledge it is impossible to form compounds of a lower ratio of carbon and hydrogen than that existing in acetylene, C_2H_2, and while there are many substances of the same numerical atomic ratio, they have an increased number of atoms to the molecule, as for example, benzene, C_6H_6. It is found that the greater number of atoms present the smaller the illuminating power; thus acetylene, C_2H_2, has a candle power of 240, while that for benzene, C_6H_6, is 126; continuing the series, many oils of lesser candle power are obtained, reaching finally a brown oil of indeterminate absolute composition which is practically incombustible.

Acetylene Generators.—The design and construction of acetylene generators, particularly in the United States, has shown a marked improvement in the past few years, a result due in part to the competition among manufacturers, partly to the increasing knowledge of the requirements of the industry among buyers, and in large measure to the insurance interests of the country. Within the past three years the fire insurance companies in the United States, through the National Board of Fire Underwriters, have organized a laboratory at 67 E. 21st Street, Chicago, Ill., at present in charge of Mr. W. H. Merrill, for the examination of all fire hazards and fire prevention devices, which naturally includes acetylene apparatus. Acetylene generators constructed in accordance with the rules of the committee, and upon passing prescribed tests, are placed upon the so-called "List of Permitted Machines," which placement is in most cases followed by the consent of the insurance companies to the installation of that apparatus within insured premises with no addition to the rate of insurance.

During 1901 the Engineers' Committee of the Board increased the requirements relating to acetylene apparatus and a systematic re-examination of previously permitted machines was vigorously enforced, which resulted in the removal from the "permitted list" of 79 machines. This, with the addition of 34 new ones, brought the net total on the list at the close of the year to 100. Late in 1901 a standard for the examination of acetylene table lamps and other portable apparatus was adopted by the Engineers' Committee, under which an acetylene lamp to be placed upon the permitted list must be practically free from fire hazard. One table lamp was placed upon the permitted list, and its rapid introduction was promptly begun by the manufacturer, as a pronounced demand has always existed for a lamp of this character.

The United States Post Office granted during the year 129 patents for acetylene apparatus, making a total of 959 patents in this class.

In Europe the manufacturers of acetylene generators have confined themselves almost exclusively to machines of the non-automatic type, in most of which enough carbide is fed into the water in the machine, by hand, to generate a sufficient supply of gas to last during the daily lighting hours. This plan requires the use of a holder of sufficient capacity to contain gas for a maximum requirement of 24 hours. Generators of this type, however, are not installed in the buildings to be lighted. Automatic generators in Europe are comparatively crude, and none are sufficiently well designed or constructed to pass the requirements of the insurance interests of the United States. Usually automatic machines require some extraneous source of power for the operation of the feeding mechanism,

which complicates the operation. It is noted that most generators are equipped with chemical purifiers to remove impurities from the acetylene produced from carbide manufactured in Europe, while in America purifiers are not used, a distinction probably due to the difference in the purity of the raw material procurable in the two countries for the manufacture of carbide.

Lamps.—In England and Germany many portable acetylene lamps are manufactured, particularly for automobiles, carriages and bicycles, although a portable lamp for indoor use has not yet been marketed. In America, the passing of the general use of the bicycle, has greatly diminished the use of acetylene in portable lamps; but the introduction of table lamps and apparatus for automobile and carriage lighting, bids fair to take the place of the large consumption previously absorbed by bicycle lamps.

Car Lighting.—During the year the use of acetylene for lighting railroad passenger cars has greatly increased throughout Europe and America, and experiments were conducted in coach or in engine lighting by many railroads in the United States. In Germany, where the greatest quantity of acetylene is used for coach lighting, the Government railroads use it as an enricher for gas of low candle power, the resultant mixed gas containing about 25% acetylene and 75% of a gas made from shale. It is estimated that 5,500 tons of calcium carbide is consumed annually in Germany for making acetylene for car lighting purposes. In German practice the mixed gases are compressed in storage tanks under the cars at about 150 lb. per sq. in. The gas is handled and utilized in a similar manner to the Pintsch oil-gas for lighting cars.

In the United States most of the experimenting with acetylene car lighting has been confined to the use of automatic generators located within the car to be lighted. Four separate concerns are exploiting this system of car lighting in the United States, one of which has introduced generating and compressing plants for the lighting of cars with acetylene from central stations, using storage tanks on the cars for the compressed gas. Apart from Germany there has been little commercial progress made in the use of acetylene for car lighting in Europe.

The Great Northern Railroad in the United States has 75 passenger coaches lighted by this gas, and 80 additional cars are being equipped with the apparatus. The system in use consists of compressing acetylene to 150 lb. per sq. in., storing the compressed gas in tanks under the cars, and providing against accidents from dissociation in case of fire by the use of connections which fuse at a low temperature.

Acetone.—The use of acetone[1] as an absorbent in connection with acetylene has received much attention during the year, particularly for car lighting, and several coaches on a prominent railroad in the United States are lighted experimentally by this method. By using a storage tank filled with acetone, the volume of acetylene which can be stored therein is increased once for each pound pressure. Excellent results were obtained by placing the acetone in storage tanks filled with

[1] Acetone is a colorless mobile liquid which boils at 56·3°C., mixes with water in all proportions, and is an excellent solvent for the gases of the hydrocarbon series. It may be produced commercially according to the Squibb method by passing acetic acid vapor through a rotating iron cylinder, heated to 500° to 600°C., which contains pumice stone and precipitated barium carbonate. A cruder method of production is from the dry distillation of calcium acetate.

porous brick to facilitate the absorption. An additional advantage is claimed for the porous brick, in that dissociation is localized in the event of its occurrence. While the method of storing acetylene in acetone was developed in France, its commercial development has made but little progress in that country.

Power and Fuel Purposes.—The use of acetylene for power or other fuel purposes has made but little progress and it is improbable that the general use of acetylene in this field will advance, unless for some special power purpose, as an automobile motor. Notwithstanding the economy in the use of acetylene as an illuminant, it cannot be used economically as a fuel, for its heating value is not in proportion to the cost per 1,000 cu. ft. or other unit of value of other fuels.

Central Plants for Illumination.—During 1901 small municipalities and local capital have investigated the feasibility of supplying acetylene from centrally situated plants to consumers located within reasonable distances. In France the introduction of these plants has made rapid progress. Forty central plants are reported in operation in that country of which 15 are constructed on the Turrs system for the distribution of gas. This system provides for the distribution of the gas through 0·5-in. to 2-in. lead pipes with wiped joints, with the gas compressed to about 0·5 lb. per sq. in., an unusually high pressure, but one that is necessary on account of the small size of the pipes. It is claimed that the cost of lead-pipe construction does not exceed the cost for wrought or cast-iron gas mains, and the very important element of leakage is eliminated. The Turrs plants are erected and operated by a private corporation which is reported to have been very successful.

There are 36 town-lighting plants in operation in Germany, and six in England, while in America 40 plants are in operation or under construction. These figures do not include a few large plants which furnish acetylene to groups of buildings, but which cannot fairly be designated as town-lighting plants.

The use of acetylene throughout the world is confined to illumination, its use for chemical or other purposes being practically negligible. Probably 65% of the world's consumption of acetylene is in individual plants for lighting single buildings, most of which are located beyond the reach of gas or electric companies selling illumination even at the low figures prevailing in the large cities.

Publications.—A number of periodicals devoted exclusively to the acetylene industry are published regularly, three in Germany, two in France, two in England, and one in the United States. In addition many trade papers devote considerable space to this important industry.

Exhibits.—At the Pan-American Exposition at Buffalo, N. Y., was an elaborate exhibition and display of acetylene and its appliances. The acetylene building was specially constructed and illuminated with 5,000 jets, many being on the exterior. The educational advantages of this display of acetylene apparatus have since been felt by the industry. In addition to the acetylene building, others in the Exposition were lighted by acetylene, principally the large railroad station and the transportation building. The central plant supplying all buildings had a daily output of 10,000 cu. ft., and at that time was the largest acetylene installation in the world.

The annual meeting of the International Acetylene Association was held at

Buffalo, June 20 and 21, 1901, within the grounds of the Pan-American Exposition, and the complete proceedings, including all papers read, were published as a supplement to *The Acetylene Gas Journal.*

Calcium Carbide.—During 1901 practically no increase was made to the world's calcium carbide manufacture. In previous years the demand was so far anticipated that even at the close of 1901 the manufacturing capacity was at least four times greater than the market requirements. This condition of over production was universal, with the possible exception of Great Britain, and was most noticeable in countries where private ownership of patents did not restrict the erection of plants. The extraordinary rate at which plants for manufacturing this product were erected may be attributed to several causes, chief among which are (1) a spasmodic demand, making it utterly impossible to judge future requirements, (2) a universal belief that the profit in manufacturing this product is very large, (3) the activity of manufacturers of electrical apparatus seeking a market for their goods but without direct interest in the permanency of the carbide business, (4) a general lack of appreciation of the fact that the demand for carbide is dependent primarily upon the progress of the business of introducing acetylene apparatus for illuminating purposes.

On the European continent, allowing a reasonable rate of increase in the consumption of acetylene, it will probably require 10 years before the demand for calcium carbide equals the present manufacturing capacity. It is evident as well that without improved processes the present plants will not meet future trade requirements.

Plants for the manufacture of calcium carbide are located in the principal countries as follows: Germany, 7; Austria, 8; Spain, 2; Italy, 4; Norway, 3; Sweden, 4; Switzerland, 13; France, 21; Finland, 2; Russia, 2; England, 2; United States, 2; Canada, 2; Argentine Republic, 1; total, 73; and in the aggregate 254,350 H.P. is installed for the manufacture of this product, of which, however, but 63,900 H.P. is in use at present.

The association of calcium carbide manufacturers in Germany, Switzerland, Austria and Sweden, formed late in 1900, with central sales office at Frankfort, has been disbanded, but a second attempt is now being made to regulate the production of carbide in Germany.

Markets.—During 1901 a decided increase in the selling price of calcium carbide was made on the European continent, due to the formation of a syndicate of manufacturers which was organized for the purpose of limiting production and maintaining prices, a plan necessary on account of previous competition and ruinous prices. The syndicate is said to include all the manufacturers in Europe except those in Great Britain and Italy. Previous attempts to maintain similar arrangemeints in the same territory failed for lack of complete co-operation. The realization of the absolute necessity for maintaining prices and the apportionment of the actual demand, bids fair to maintain the present combination. The selling prices to dealers of the Continent, established at the time of the formation of the syndicate, were about $71·50 per ton, including packages, f. o. b. several distributing points. Owing to competition, this price was quickly reduced to about $64·25 per ton, where it will probably remain.

In the United States a radical change in method of distribution was adopted, which resulted in a uniform price for carbide over practically all the section east of the Rocky Mountains. This was accomplished by the establishment of warehouses at all important centers which supplied carbide at $70 per ton including packages, f. o. b. cars at each of the distributing points. As a result large reductions were made in the cost to consumers, amounting in some sections to nearly $25 per ton.

Tariff.—The United States exacts an ad valorem duty of 25% upon importation of calcium carbide; Canada, 25%, while Germany, Belgium, Greece, Netherlands, and Norway admit it free. The following ad valorem duties are assessed on production: Bulgaria, 14%; Denmark, 10%; France, 5%; Sweden, 15%; Italy exacts a specific duty of $21·80 per ton and Switzerland, $14·52.

Transportation.—In Europe, while there are no special regulations by the transportation companies as to the package in which calcium carbide shall be shipped, the material is nevertheless considered hazardous and freight rates are levied accordingly. The railroad companies in the United States specify weight and construction of packages, and classify the material so that reasonable freight rates prevail.

Furnace Practice.—In Europe the prevailing custom is to remove calcium carbide from the furnaces by the so-called "tapping" process, while in America the ingots are taken directly from the furnace. It is now conceded that a more uniform quality can be produced by the latter method, and the greater purity of the raw materials in America yields a higher grade of calcium carbide than that generally produced in Europe.

Sizes of Carbide.—Various devices for generating acetylene gas have required the carbide to be crushed and screened to different sizes in order to insure a satisfactory operation of the apparatus. The manufacturers in Great Britain furnish nine sizes varying from pieces 0·5 in. to 5 in. in size. Germany has three commercial sizes; Austria, four; America four, and Canada four. The smaller sizes produce proportionately less gas than the larger ones, due to the losses in acetylene owing to increased aggregate surface exposed during packing and handling. Because of the comparative ease of construction of a mechanism to feed the smaller sizes of carbide automatically, it is noted that the generator manufacturers are inclined to construct generators on this plan. This sacrifice of efficiency, however, is leading to the manufacture of apparatus which will handle the larger sizes successfully.

Quality of Carbide.—The manufacturers in Great Britain and in the United States guarantee a yield of 5 cu. ft. of acetylene gas per pound of the larger size carbide. In France there is no guarantee or legal regulations, and the quality is said to vary from about 4·75 cu. ft. of gas per pound to 3·70 cu. ft., the general average being probably 4·34 cu. ft.

In Europe the standard of quality is 4·81 cu. ft. of gas per pound of carbide, though in many cases the yield is below that figure and an allowance is made accordingly.

In Germany rules have been adopted which provide that the average yield from a given package shall be 4·65 cu. ft. of gas per pound at 15°C. and at 29·92 in.

barometric pressure, 2% variation from the standard being allowed. The buyer is obliged to accept carbide yielding as low as 4·25 cu. ft. of gas, although a proportionate allowance is made. Material yielding under 4·25 cu. ft. per pound need not be accepted. Specific means for taking samples and making tests are provided.

A broad view of the carbide and acetylene industries indicates a steady and healthful growth upon legitimate lines and at only fair manufacturers' profits. Most of the false impressions concerning the possibilities of the business have been corrected, and the losses which have been sustained will probably deter overproduction and ruinous competition in the future.

CARBORUNDUM.

THE carborundum industry during 1901 continued to show great progress, and the sole manufacturer using two units of 1,000 H.P. each, produced 3,838,175 lb. of crude carborundum, valued at $345,435, as compared with 1,741,245 lb., valued at $216,090 in 1900. Of the production in 1901, 1,414,694 lb. was used in the company's factory for the manufacture of wheels, paper, cloth, etc.; 487,682 lb. was sold in the form of grains and powders for abrasive purposes; and 1,693,774 lb. was disposed of to steel makers for use as a substitute for ferro-silicon. A very conservative estimate of the relative values of carborundum and emery for abrasive purposes makes 1 lb. of the former equivalent to 3 lb. of the latter and from this it follows that carborundum as an abrasive replaced, last year, about 5,700,000 lb. of emery. Assuming that ferro-silicon averages 15% Si, 4 lb. of that material is replaced by 1 lb. of carborundum, so that the carborundum produced in 1901 replaced about 6,800,000 lb. of ferro-silicon.

The consumption of carborundum is increasing so rapidly that preparations are being made to install an additional 1,000-H.P. unit in the factory at Niagara Falls, an increase which will give a total annual production of approximately 5,800,000 lb. of carborundum.

It is interesting to note that in the original patent for carborundum, stress was laid on its great "refractability and infusibility"—two valuable properties, the practical value of which is now beginning to be recognized.

CEMENT.

THE production of Portland cement in the United States during 1901 exceeded that of the previous year by 4,719,586 bbl., the increase coming almost entirely from the Portland cement mills of Pennsylvania, New Jersey and Michigan. The production of natural hydraulic cement during 1901, however, decreased 2,000,000 lb. from that of 1900, and the output of slag cement also showed a large proportionate decrease.

PRODUCTION OF PORTLAND CEMENT IN THE UNITED STATES. (IN BARRELS OF 400 LB.)

States.	1900.			1901.		
	Barrels.	Value at Works.		Barrels.	Value at Works.	
		Total.	Per Bbl.		Total.	Per Bbl.
California	51,000	$122,200	$2·20	146,848	$513,968	$3·50
Michigan	598,407	881,786	1·39	1,025,718	1,128,290	1·10
New Jersey	1,220,000	1,564,700	1·28	1,612,000	1,450,800	0·90
New York	446,664	611,930	1·38	617,228	617,228	1·00
Ohio	498,404	752,521	1·51	519,952	571,887	1·10
Pennsylvania	4,807,664	5,961,503	1·24	7,091,500	6,382,350	0·90
South Dakota	40,000	80,000	2·00	(b)	.....	.....
Utah	71,500	143,000	2·00	(c)	.....	.....
Other States (a)	258,000	394,200	1·53	1,698,079	1,867,887	1·10
Total	7,991,639	$10,461,910	$1·31	12,711,225	$12,532,360	$0·98

(a) Includes Arkansas, Illinois, Indiana, Kansas, Virginia, North Dakota, and Texas. (b) Included in Other States. (c) Included in California.

PRODUCTION OF NATURAL HYDRAULIC CEMENT IN THE UNITED STATES. (IN BARRELS OF 300 LB.)

States.	1900.			1901.		
	Barrels.	Value at Works.		Barrels.	Value at Works.	
		Total.	Per Bbl.		Total.	Per Bbl.
Illinois	377,579	$116,500	$0·31	469,842	$187,936	$0·40
Indiana and Kentucky	3,488,392	732,562	0·21	2,150,000	752,500	0·35
Kansas	127,339	50,933	0·40	145,760	72,880	0·50
Maryland	195,242	80,418	0·42	351,329	175,665	0·50
Minnesota	56,403	28,201	0·50	(b) 126,000	63,000	0·50
New York:						
Ulster County	2,745,000	2,333,250	0·85	1,184,007		
Onondaga County	139,765	72,498	0·52	141,622		
Schoharie County	*Nil.*	*Nil.*	*Nil.*	62,702	1,117,066	0·50
Erie County	749,890	329,952	0·44	663,800		
Other counties	.....	.....	.....	182,000		
Ohio	25,000	15,000	0·60	(c) 104,000	62,400	0·60
Pennsylvania	703,612	281,445	0·40	942,384	376,954	0·40
Virginia	75,000	45,000	0·60	(d)	.....	.....
Wisconsin	412,000	156,560	0·38	481,020	182,788	0·38
Other States (a)	82,000	66,400	0·81	80,357	65,089	0·81
Total	9,177,222	$4,308,709	$0·47	7,084,823	$3,056,278	$0·43

(a) Includes Georgia, Tennessee, West Virginia, Texas and Nebraska. (b) Includes North Dakota. (c) Includes Virginia and West Virginia. (d) Included in Ohio.

Slag Cement.—The output of slag cement was 272,689 bbl., of 400 lb., valued at $198,151, against 490,150 bbl. ($622,490) in 1900. The average price declined strongly, in order to meet the competition of Portland cement which, in addition to its superiority for most purposes, sold at very low figures in the large manufacturing centers. There were six plants in operation, the same as in the previous year. By the decision of a board of engineers officially appointed, it has been decided that "Steel Portland Cement" cannot be substituted for Portland cement in government work where the specifications call for the latter, but is to be classed as puzzolana slag cement. The slag cement industry of the United States is given in detail in the special monograph by Mr. E. C. Eckel, later in this section.

CEMENT PRODUCTION, IMPORTS, EXPORTS AND CONSUMPTION IN THE UNITED STATES. (IN BARRELS OF 300 LB.)

Year.	Production.				Imports.		Exports. (b)		Consumption.	
	Natural Hydraulic.	Portland. (a)	Total Barrels.	Value.	Barrels.	Value.	Barrels	Value.	Barrels.	Value.
1897.....	7,890,573	3,294,537	11,185,110	$7,760,955	2,787,766	$2,668,122	79,588	$108,389	13,893,293	$10,345,688
1898.....	8,161,078	4,989,664	13,150,742	10,223,822	2,695,092	2,624,228	70,892	98,121	15,764,942	12,749,929
1899.....	9,686,447	8,067,161	17,753,608	15,860,731	2,810,951	2,858,286	147,029	213,457	20,417,530	18,505,560
1900.....	9,177,222	11,309,052	20,486,274	15,393,109	3,182,245	3,330,445	186,586	289,186	23,481,933	18,434,368
1901.....	7,084,823	12,983,914	20,068,738	15,588,688	989,330	1,305,692	417,695	752,057	20,590,443	16,142,273

(a) Includes slag cement. (b) Includes re-exports of foreign.

IMPORTS OF CEMENT INTO THE UNITED STATES ACCORDING TO SOURCE.

Year.	Belgium.		Canada.		France.		Germany.	
	Short Tons.	Value.	Short Tons.	Value.	Short Tons.	Value.	Short Tons.	Value.
1897.....	109,531	$649,675	981	$9,311	7,545	$44,574	221,856	$1,467,845
1898.....	133,806	80,949	955	8,852	3,459	22,224	206,982	1,394,551
1899.....	124,830	747,448	880	8,868	3,130	22,262	238,799	1,698,722
1900.....	165,258	1,001,122	903	9,396	6,542	47,793	231,110	1,722,104
1901.....	60,636	377,517	1,213	12,180	2,354	20,421	111,008	804,710

Year.	United Kingdom.		Other Countries.		Total Imports.		Exports. (a)	
	Short Tons.	Value.	Short Tons.	Value.	Short Tons.	Value.	Short Tons.	Value.
1897.....	68,869	$451,256	9,380	$65,461	418,165	$2,668,122	11,937	$103,389
1898.....	47,212	333,405	10,350	64,247	402,764	2,624,228	10,633	98,121
1899.....	39,927	309,614	14,112	76,372	421,643	2,858,286	22,054	213,457
1900.....	53,584	416,937	19,939	133,093	477,337	3,330,445	27,968	289,186
1901.....	7,478	58,570	5,177	32,294	187,866	1,305,692	83,525	752,057

(a) Estimated from number of barrels reported at 1 bbl.=400 lb. Includes re-exports of foreign.

THE CEMENT INDUSTRY IN THE UNITED STATES DURING 1901.

BY FREDERICK H. LEWIS.

PORTLAND CEMENT.—The production of Portland cement during 1901 presented the same extraordinary conditions as those which prevailed during the previous year,—an enormous output, extremely low prices, and a number of new plants projected or under construction in various parts of the country. The output was considerably larger than that of the previous year, and the stock of cement on hand at the end of 1901 was undoubtedly smaller than at the end of

1900. With the enormous amount of construction work in view in all parts of the country, it seems probable that the output for 1902 will be wholly absorbed and better prices will be realized than for two years past, a result much to be desired, as profits of manufacture have been unsatisfactory; indeed the smaller and less favorably located plants have had no profits for several years.

While nothing new or novel has developed in the process of manufacturing cement in the United States, the general tendency has been to bring greater mechanical skill to bear on the development of the industry. In recent years the expert mechanical engineer has found an extremely interesting field of work in the improvement of facilities and details for the manufacture of Portland cement, and the economies realized have been due almost entirely to the skill which has been applied along this line.

The rotary kiln process has become permanently established as the distinctive American method of making cement, although it has also been used to a considerable extent abroad. The reports of the operation of rotary kilns at the Hemora plant in Germany indicate that it is quite successful in working wet materials and that the product is decidedly superior to that produced by the continuous shaft kilns previously in use.

The report on cement of Messrs. Stanger & Blount, which was read before the Institution of Civil Engineers, and the discussion thereon form a very interesting and valuable contribution to the industry. Messrs. Stanger & Blount were employed as experts by an English syndicate to examine into the American rotary process of making cement, particularly with reference to the work of the Atlas Cement Co., which uses certain devices patented by Messrs. Hurry & Seaman, in this country and in England. The English syndicate was organized to purchase the English patents of the devices and to use them in a very large plant or a series of plants promoted chiefly by the old English cement firm of J. B. White & Co. Whether the rotary process will be successful under the English conditions of materials, labor, and fuel remains to be seen, but it seems quite evident that it will be tried on a large scale in the near future. The success of the rotary kiln process for wet materials in America is not yet firmly established or clearly demonstrated. In England and the Continent the cost of fuel at the present time is undoubtedly higher than it is in America, and the success or failure of applying this process abroad, on wet materials, will be watched with much interest.

The quality of the domestic Portland cement marketed in the United States during 1901 was superior to that produced in previous years, as well as being of better quality than the foreign brands of this commodity; a fact which has been fully confirmed by tests and analyses. This has resulted from the increased application of the rotary kiln on raw materials, equally as good as those used abroad.

The methods of testing Portland cement and the proper requirements of specifications for this product, still remain a vexed question. The committee on the methods of testing appointed by the American Society of Civil Engineers, under the chairmanship of Prof. George F. Swain, has done very conscientious work during 1901 in the endeavor to develop acceptable rules. The subjects under discussion have been divided among the members of the committee, and numerous

special reports have been presented and discussed. At the close of the year the matter was in sufficient shape to make a preliminary draft of the method of tests, which will be further developed and improved during the year 1902, and will probably be reported to the Society at the close of that year. Undoubtedly the methods proposed, if adopted by the Society, will be very generally adopted by the engineering profession and will result in a much greater uniformity of tests and a much more general consensus of opinion in regard to the proper criteria to be used in judging the quality of Portland cement.

The New York section of the Society of Chemical Industry appointed a committee in April, 1901, to report on "Uniformity in Technical Analysis." This committee appointed a sub-committee to deal with the methods of analysis of materials pertaining to Portland industry, with Mr. Clifford Richardson as chairman, and the co-operation of 17 representative chemists was secured, all of whom analyzed the same samples of materials and reported to the chairman. The results obtained were subsequently reviewed by Mr. W. F. Hillebrand, of the United States Geological Survey, and together with the methods of analysis suggested by Mr. Hillebrand, were reported to the Society on December 20, 1901. The value of this report can hardly be overestimated, and its advantages to chemists engaged in this industry as a basis of standardizing their work will be very generally recognized. On account of the length of the report, it is not practicable to include even an abstract of it in these pages, and reference should be made direct to the original publication.

New Plants in Operation.—In Alabama, the Alabama Portland Cement Co., at Demopolis, placed three rotary kilns in operation, using argillaceous limestone.

In Michigan, the Newago Portland Cement Co. operated a 3-kiln plant at Newago, on the Muskegon river, using marl and clay in the manufacture of cement, and utilizing the water power of the Muskegon river for power purposes. The Alpena Co., at Alpena, has a plant of rotary kilns.

In New Jersey the new 10-kiln plant of the Alpha Cement Co. went into operation.

In New York, the Helderberg Cement Co., at Howes Cave, Schoharie County, placed a new plant in operation during 1901, of a nominal capacity of 1,500 bbl. per day. The raw materials are hard limestone of the Water Lime Group in New York State, and clay. The Glens Falls plant, which was destroyed by fire a year or two ago, was rebuilt and placed in operation.

In Pennsylvania, the Northampton plant, in Northampton County, operated with six standard rotary kilns, and the American Cement Co., at Egypt, placed several new rotary kilns in operation during the year.

Plants Projected or Under Construction.—In California, the Pacific Portland Cement Co. has under construction a modern rotary-kiln plant at Suisun, where there is a large deposit of pure limestone which will be utilized in connection with a blue-clay deposit in the marshes of that vicinity. The Pacific Co. will place three kilns at once, so arranged that seven additional kilns can be installed. Electric power developed from water power will be used throughout, and the fuel will be petroleum oils from southern California. The plant will be equipped with modern machinery and, as it will be operated under

the most advantageous conditions for power and kiln-fuel for this locality, it is expected to make cement at a moderate cost, and to be able to reduce its price on the Pacific coast to a more reasonable figure than that now maintained. The Eureka Portland Cement Co. is reported to be building, or about to build, a plant in the same locality. The California Cement & Lime Co. has been incorporated with the idea of building a cement plant in San Joaquin County, not far from Stockton. The only plant in operation at present in California is that of the California Portland Cement Co., at Colton. This plant operates two rotary kilns on hard limestone and soft clay.

In Colorado, the Colorado Portland Cement Co. and one other propose to erect plants near Florence.

In Indiana, the Lehigh Portland Cement Co. has under construction an 8-kiln plant at Mitchell. The materials to be used are hard limestone and clay.

In Michigan, the Great Northern Portland Cement Co. has under construction a large plant at South Baldwin, and the Bellaire Portland Cement Co. has been organized at Bellaire.

In Missouri, at Hanover, the Atlas Portland Cement Co. has purchased a tract of land and placed under construction a large plant to handle its Western trade. The material is hard limestone, which will be used with a suitable mixture of clay to produce a Portland cement. The St. Louis Portland Cement Co. is building a plant at Prospect Hill, near Baden.

In New Jersey the Edison Co. has a large plant projected at Stewartsville, which is expected to place cement on the market during 1902. The Capital Portland Cement Co. has been incorporated, and is reported to have purchased land near the Edison plant, at Stewartsville, for the erection of a large plant. The Marksboro Portland Cement Co. has projected a plant at Marksboro, Warren County, to use marl from White Lake.

In New York, the plant of the Alsen American Co., on the west bank of the Hudson river, near Catskill, has been under construction during the year and will probably go into operation in the spring of 1902. It is stated to be a well-equipped American plant with the improved features of an European plant.

In Pennsylvania, the Lehigh Co. has started the erection of a third plant of eight kilns near Ormrod.

In Texas, at Dallas, a plant has been projected to manufacture cement for the Southern trade.

In Virginia, the Virginia Portland Cement Co., at Craigsville, has placed contracts for doubling its original plant, and the enlarged plant is expected to be in operation during the summer of 1902.

In West Virginia, the Buckhorn Portland Cement Co., at Rollsburg, has still been unable to complete its plant, owing to financial difficulties which required the plant to be sold by a receiver. In all probability this plant will ultimately be completed and will become a feature in the market.

In addition to the above projects, several others in various parts of the country have been reported, particularly in the South, but the information is not sufficiently definite to warrant notice.

In Canada, the National Portland Cement Co. is reported to be building a large plant at Durham, Ont., with offices in Toronto.

NATURAL HYDRAULIC CEMENT.—There has been a very large sale of natural cement during 1901 and an increase in production. The Pennsylvania plants, having a natural raw material which can be utilized for this purpose, are increasing to some extent their facilities for making natural cement, and plants which have not produced it heretofore are now taking up its manufacture. The Vulcanite Co., at Vulcanite, N. J., is reported to be building, or about to build, natural cement kilns. A very excellent grade of American cement is made from a mixture of Portland and natural cement, which can be sold at a considerably lower price than for Portland cement alone. In the Ulster County, N. Y., district some consolidations of interests are reported. In Alabama, the Chickamauga Cement Co. is reported to be building a large plant at Rossville, Ga.

The Slag Cement Industry in the United States during 1901.

By Edwin C. Eckel.

At the present time blast-furnace slag is used in three very different ways in cement manufacture and the methods should be sharply distinguished, as the resulting products are widely different in their properties. The uses of slag referred to are the following:—

(1) Granulated basic blast-furnace slag is intimately mixed with slaked lime, and the mixture is pulverized, giving a slag cement. This product, though usually called a Portland cement by its manufacturers, is unlike a true Portland in both its ultimate and rational compositions and in the processes through which it has passed. Further than this, and more important from the engineer's standpoint, a cement of this class has certain qualities which prevent its being used as an exact substitute for a Portland cement. About half a dozen plants are engaged in the manufacture of this material in the United States, while a large number of works make it in England and in continental Europe.

(2) Slag is mixed with limestone; and the mixture pulverized, calcined and reground, giving a true Portland cement. The "Universal" Portland brand of the Illinois Steel Co. is made in this manner, and the process is becoming somewhat largely employed in continental Europe, though it does not seem to have taken root in England. Absolutely no objections can be urged against cements produced in this fashion, for in composition, methods of manufacture and qualities of the product they agree entirely with Portland cements made from limestone or marl and clay.

(3) Powdered slag is added to Portland cement, either after the clinker has been ground, or during the final stages of the grinding. In this case the slag is used merely as an adulterant. While it seems certain that it can be of no benefit to the cement, it is almost equally certain that it is not actively detrimental. In fact, were the mixing and the grinding managed carefully enough, the resulting product might be regarded as falling approximately in the class of sand-cements. As it is, however, the case is simply one of adulteration carried on in order to decrease the cost of the product.

In this connection another use of slag should be referred to, though in this case the slag is added by the engineer, not by the manufacturer, and serves a distinctly useful purpose. The use alluded to is:—

(4) The addition of slag to Portland cement intended for use in sea water.

The following paper is confined strictly to a discussion of the material produced by the first mentioned use of slag resulting in a slag cement, of the class of pozzuolanic cements.

Slag cement is composed of an intimate mechanical mixture of slaked lime and granulated blast-furnace slag of suitable chemical composition; both materials being finely pulverized before, during or after mixing. The process of manufacture includes the granulating and drying of the slag, the slaking of the lime, the mixing of these materials and the grinding of the resulting cement, together with any means which may be employed for the regulation of the setting time of the cement.

The seven (or eight) slag cement mills operating in the United States advertise their product as Portland cement, a position which seems to be indefensible, even from the point of view of sound business policy. Slag cements possess some qualities which Portlands lack; and could, it would seem, be sold on their merits. So far as cost of manufacture is concerned, slag cements can be sold at lower prices than "natural" cements, though they are generally quoted at much higher rates.

The slag cements manufactured in this country are far superior to those of Europe in tensile strength, soundness, etc. Regulation of set is invariably practiced, the result being that American slag cements set as rapidly as Portlands. Most of the American plants are directly connected in ownership, with iron companies. This is necessary if a supply of proper slags is to be obtained.

Composition of the Slag.—The slag used in cement manufacture must be basic blast-furnace slag. Tetmajer, the first investigator of slag cements, announced as the results of his experiments (*a*) that the hydraulic properties of the slag increased with the proportion of lime contained in it, and that slags in which the ratio $\frac{CaO}{SiO}$ was so low as to approach unity were valueless for cement manufacture; (*b*) that, so far as the alumina content of the slag was concerned, the best results were obtained when the ratio $\frac{Al_2O_3}{SiO_2}$ gave a value of 0·45 to 0·50; and (*c*) that with any large increase of alumina above the amount indicated by this value of the alumina-silica ratio, the tendency of the cement to crack (when used in air) was increased.

Prost, at a later date, investigated the subject, using for experiment several commercial slags and also a series prepared from pure CaO, SiO_2, and Al_2O_3. He decided that the hydraulic properties (both as regards rapidity of set and ultimate strength) of the slag increased as the proportions of lime and alumina increased; and failed to find any indication that a high alumina content causes disintegration. His best results were obtained from slags having the compositions respectively of $2SiO_2$, Al_2O_3, 3CaO and $2SiO_2$, Al_2O_3, 4CaO.

Mahon, in 1893, made a series of experiments to determine the value (for cement manufacture) of a large series of the slags produced by the furnaces of the Maryland Steel Co.; and found that the slags giving the best results were two having respectively the following compositions:—

(1) SiO_2, 30%; Al_2O_3, 17%; CaO, 47·5%; S, 2·38%; and (2) SiO_2, 25·3%; Al_2O_3, 20·1%; CaO, 48%; MgO, 3·28%; S, 2·63%.

The ratios of $\frac{CaO}{SiO_2}$ and $\frac{Al_2O_3}{SiO_2}$, calculated for these slags are:—

(1) $\frac{CaO}{SiO_2}=1·58$; $\frac{Al_2O_3}{SiO_2}=0·57$; and (2) $\frac{CaO}{SiO_2}=1·9$; $\frac{Al_2O_3}{SiO_2}=0·79$.

At the close of the experiments Mahon recommended that slags be used even slightly higher in alumina than those above quoted.

The specifications under which slag from the furnaces is accepted by the cement department of the Illinois Steel Co., are:—

(1) Slag must analyze within the following limits:—

$SiO_2+Al_2O_3$ not over 49%; Al_2O_3, from 13 to 16%; MgO, under 4%.

(2) Slag must be made in a hot furnace and must be of a light gray color.

(3) Slag must be thoroughly disintegrated by the action of a large stream of cold water directed against it with considerable force. This contact should be made as near the furnace as is possible.

A series of over 300 analyses of slags used by this company in their slag (pozzuolanic) cement, show the following range in composition:—

SiO_2, 29·60 to 35·60%; Al_2O_3 and Fe_2O_3, 12·80 to 16·80%; CaO, 47·99 to 50·48%; MgO, 2·09 to 2·81%.

The requirements of the Birmingham Cement Co. as to the chemical composition of the slags used for cement are: that the lime content shall not be less than 47·9%; that the silica and lime together shall approximately amount to 81%; and that the alumina and iron oxide together shall equal from 12 to 15%.

Analyses of a number of slags used in cement manufacture are shown in Table I. The analyses of foreign slags are quoted from various reliable authorities and the five analyses of the Illinois Steel Co. slags have been selected from a large series to show the extreme ranges of the different elements. The ratios $\frac{CaO}{SiO_2}$ and $\frac{Al_2O_3}{SiO_2}$ have been calculated for each slag and are shown in this table.

From these data it can be seen that the ratio of alumina to silica is carried very high at Choindez; and is rather low at Chicago, relatively to most of the European plants. It must be remembered, however, that one reason for carrying a high alumina-silica ratio does not apply at Chicago, as there rapidity of set is gained by the use of the Whiting process. Taking these two plants as representative of the best European and American practice, the average of the analyses given shows the ratios actually used to be: Choindez, Switzerland, $\frac{CaO}{SiO_2}=1·71$, $\frac{Al_2O_3}{SiO_2}=0·90$; and Chicago, Ill., $\frac{CaO}{SiO_2}=1·49$, $\frac{Al_2O_3}{SiO_2}=0·44$.

These results may be compared with the theoretical ratios advised by Tetmajer, Prost and Mahon, and discussed on a previous page of the present paper.

TABLE I.—ANALYSES OF SLAGS USED FOR MAKING SLAG CEMENTS.

Components.	Middlesboro, England.		Harzburg, Germany (used at Brunswick).	Belgium.	Bilbao, Spain.		Choindez, Switzerland.			Saulnes, France.		Marnaval (used at Donjeux).		Pont-a-Mousson.	Chicago, Ill.				
SiO_2	30·00	31·50	30·72	32·51	32·90	38·00	26·88	27·33	26·24	31·65	31.50	28·35	28·00	32·00	32·20	33·10	31·80	34·30	
Al_2O_3	28·00	18·56	16·40	13·91	13·25	10·00	24·12	23·81	24·74	17·00	16·02	18·15	19·50	22·00	15·50	12·60	14·80	14·76	
FeO	0·75	....	0·48	0·48	0·46	....	0·44	0·63	0·49	0·65	0·62	1·50	..	4·00 +MgO	...	....	....	....	
CaO	33·75	42·22	48·59	44·75	47·30	46·0	45·11	45·33	46·33	47·20	46·10	47·40	45·00	42·00	48·14	49·98	49·74	48·11	
MgO	5·25	3·18	1·28	2·20	1·37	.....	1·09	0·92	0·88	1·36	.....	2·45	.....	SeeFeO	2·27	2·45	2·29	2·66	
CaS	1·90	.....	2·16	4·90	3·42	.....	1·86	1·34	0·59	....	.....	.....	.....	.....	.....	.....	.....	.....	
$CaSO_4$	.....	.....	.....	.....	.....	.....	.....	0·17	0·32	.....	.....	.....	.....	.....	.....	.....	.....	.....	
SO_3	.....	0·45	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
S	.....	2·21	.....	.....	.....	.....	.....	.....	.....	.....	.....	1·40	.....	.....	.....	.....	.....	.....	
MnO_2	0·60	0·44	Tr.	0·60	1·18	.....	0·50	.....	.....	0·85	.....	.....	.....	.....	.....	.....	.....	.....	
$\frac{CaO}{SiO_2}$	1·09	1·34	1·58	1·37	1·44	1·21	1·68	1·67	1·78	.....	1·46	1·67	1·61	1·31	1·49	1·51	1·56	1·40	
$\frac{Al_2O_3}{SiO_2}$	0·93	0·59	0·53	0·43	0·41	0·27	0·89	0·87	0 93	.....	0·52	0·64	0·69	0·68	0·48	0·38	0·46	0·43	

Physical Condition of the Slag.—Slags allowed to cool slowly are only feebly hydraulic, whatever be their chemical composition, hence for use in the manufacture of slag cement, they must be cooled very rapidly. In practice this is effected by bringing the slag, immediately upon issuing from the furnace, in contact with a stream of cold water. The physical effect of this sudden cooling is to granulate the slag into porous particles. The chemical effects are two in number: One, the reason for which is not yet well understood, is to make the slag (if it be of suitable chemical composition) energetically hydraulic; the other, is to remove a portion of the sulphides in the form of hydrogen disulphide. Both of these effects are beneficial, from the point of view of the slag-cement manufacturer, and the first is absolutely necessary. As the sulphides are probably the cause of the disintegration of slag cement when exposed to dry air, the removal of even a part of the sulphur is a decided benefit.

In regard to the physical condition of the slag, Candlot further states that "the slag issuing from the furnaces at the beginning and end of a discharge is usually rejected, because of the bad effect of the chilling which attends its slow movement. For the same furnace, the spongier and bluer the slag, the more basic it is; the blacker and more vitrified, the less fit for cement."

Proportions of Lime and Slag.—Prost, in consequence of his experiments with various proportions of lime, advocated the proportion, to secure the best results, of from 35 to 40 parts of lime to 100 parts of slag. He also stated that the amounts of lime used in actual practice, for each 100 lb. of slag were: at Choindez, 40 to 45 lb.; at Donjeux, 40 lb.; at Brunswick, 33 lb.; and at Cleveland, 33 lb. Mahon, in reporting his experiments for the Maryland Steel Co., states that the best results were secured by the use of 25 parts of lime to 100 parts of slag, by weight. In the manufacture of slag brick, which is in reality merely a branch of the slag-cement industry, the amount of lime added may fall as low as 10 lb. to 100 lb. of slag.

Composition of the Lime.—According to Prost, there is no gain in tensile strength if hydraulic lime be used in place of common lime. There is, however, another benefit to be derived from this practice; for the cements made with hydraulic lime are less liable to fissure and disintegrate when used in air than are those in which a fat lime has been used. The lime used should not carry much magnesia, for this latter constituent, even though it may not be actively detrimental, is an inert material, and it should be thoroughly and evenly burned, as unburned lumps are of no service to the cement. It must then be slaked with care, as unhydrated portions would be actively detrimental. If possible, the slaked lime should not be used immediately, time being given for the air-slaking of any lumps which may have escaped hydration. The resulting material can best be mixed with the slag if given a preliminary bolting which process will remove both unburned cores and unslaked lumps. Frequently this sieving is followed or preceded by light grinding.

Chemical Composition of Slag Cements.—The ultimate composition of the material will, of course, be brought out by chemical analysis, but the fact that it is merely a mechanical mixture will not be shown in the ordinary report of such an analysis. Slag cement, when ready for sale, is a mechanical mixture of lime

hydrate ($Ca_2(OH)_2$) and a calcium aluminum silicate ($x,SiO_2,Al_2O_3,yCaO$). In addition to the essential ingredients noted above, certain others of less amount usually occur. The most important of these in the effect it produces on the quality of the product, is sulphur, which is obtained from the slag in the form of sulphides of lime or iron. To the presence of these sulphides is due, in large part at least, the disintegration of slag cements when used in dry air. If the cement be used for construction in water, their presence is of much less importance, and the total sulphides may run as high as 5% without seriously impairing the quality. Several per cent. of iron oxide obtained from the slag are commonly present. Magnesia also occurs, derived from the slag or the lime. It is inert, if not positively detrimental, and the amount should therefore be kept as low as possible.

In addition to the ingredients mentioned above, a percentage, usually small, of other compounds may be found, which have been added by the manufacturer during some stage of the process for the purpose of increasing the rapidity of set of the cement. These substances will be later discussed in the section relating to the means of hastening set.

Table II. contains the analysis of a number of American and European slag cements, as given by various authorities. It will be seen that, despite the apparently great variations in practice, the ultimate composition of the finished cement falls within quite narrow limits. The range in composition of a good slag cement may be considered to be about: SiO_2, 22 to 30%; $Al_2O_3+Fe_2O_3$, 11 to 16%; CaO, 49 to 52%; MgO, less than 4%; S, less than 1·5%; ignition loss, 2·5 to 7·5%.

TABLE II.—ANALYSES OF SLAG CEMENTS.

Components.	Brunswick, Germany (Slag from Harzburg).	Choindez, Switzerland.	Bilbao, Spain.	Donjeux.			Saulnes, France.	Chicago, Illinois.					North Birmingham, Ala.	Ensley, Ala.
SiO_2	25·56	19·5	30·56	23·85	24·85	24·55	22·45	27·20	28·40	28·95	29·80	27·80	27·0	27·78
Al_2O_3	11·20	17·5	13·31	13·95	12·10	14·05	13·95	14·18	12·80	11·40	12·30	11·10	12·0	11·70
FeO			0·25	1·10	3.85	1.85	3·30			0·54				
CaO	49·70	54·0	45·01	51·40	49·20	49·25	51·10	50·.3	51·50	50·29	51·14	50·96	55·0	51·71
MgO			2·96	1·95	1·75	1·60	1·35	3·22		2·96	2·34	2·23		1·39
S			a 4·63		1·30				1·40	1·37	1·37	1·18		1·31
SO_3			b 1·41	0·45	1·35	0·60	0·35	0·15						
Loss on ig				7·05	5·65	7·75	7·50	4·25		3·39	2·60	5·30		

(a) CaS. (b) $CaSO_4$.

MANUFACTURING METHODS.—The preliminary preparation of the materials includes the burning and slaking of the lime, and the granulating and drying of the slag. After these operations have been carried out, the materials may either be mixed immediately and the mixture ground to proper fineness in a series of mills; or the slag and lime may be ground separately, mixing being deferred until the grinding is completed. Regulation of set is almost invariably practiced at American plants, and the materials necessary to accomplish this may be added at various points in the process. Though slag-cement manufacture is simple, it will be seen that there is considerable latitude for variations in practice at different

plants. Brief sketches of the general methods in use at various plants will therefore be given; followed by a more detailed discussion of certain points of particular interest. In the granulation of the slag and the slaking of the lime little variation in practice is possible. The drying of the slag, however, is carried on in very different ways at different plants. It is an important element in the cost of the finished product, and will therefore be discussed in considerable detail. Methods of grinding, and of regulation of set, are also of both theoretical and practical importance, and are discussed at some length in the following pages.

General Practice.—The Maryland Cement Co.,[1] at Sparrows Point, Md., obtains the slag from the furnaces of the Maryland Steel Co. The slag is dried in Ruggles-Coles dryers; and, after mixing with the slaked lime, is ground in discontinuous pebble-mills. Mahon's experiments, preliminary to the establishment of this plant, are discussed on an earlier page.

The slag-cement plant of the Illinois Steel Co., Chicago, Ill., obtains its slag from the blast-furnaces of that company. The specifications under which this slag is received, with analyses showing its actual range in composition, will be found on a preceding page. After granulation and drying in a specially designed dryer the slag receives its preliminary reduction in Griffin mills. Meanwhile the lime has been slaked as described in detail on a later page of this paper, caustic soda being added to regulate the set of the product. The ground slag and this prepared lime are then mixed, and the mixture receives its final reduction in Davidsen tube-mills.

At the plant of the Birmingham Cement Co.,[2] at Ensley, Ala., slag is obtained from the furnaces of the Tennessee Coal & Iron Co., located in nearby towns. The slag is granulated at the furnaces. On arrival at the mills, carrying about 40% of water, it is dried in Ruggles-Coles dryers. Two of these, of the A2 style are in operation. After drying, the slag and slaked lime are fed together to West ball mills, four of which are in use, and the mixture is finally reduced in West tube mills.

The Southern Cement Co., at North Birmingham, Ala., dries its slag in a style A2 Ruggles-Coles dryer. The dried slag is crushed in a Kent mill. After mixing with the slaked lime, the final reduction takes place in West tube mills. Two brands of slag cement are marketed. One, a normal slag cement, is said to average about CaO 55%, Fe_2O_3,Al_2O_3 12%, SiO_2 27%. The other brand is quicker setting and carries about 10% less CaO and about 10% more SiO_2. This high silica content is due to the addition of a very highly siliceous rock, probably a pure crushed quartz.

At Skinningrove, England, slags were used of a composition varying between the following limits: SiO_2, 30 to 32%; CaO, 30 to 33%; Al_2O_3, Fe_2O_3, 25 to 28%. The slag on issuing from the furnace, was run into water; ground, before drying, under edge runners; and dried on iron plates in a drying chamber. The dried material was ground under millstones; sieved; and mixed with lime (which had been slaked and screened) in the proportions usually of lime 33 lb.

[1] Lewis, F. H., *Cement Industry*, p. 184.

[2] Eckel, E. C., *Engineering News*, Jan. 23, 1902.

slag 100 lb. The resulting cement varied in composition between the following limits: SiO_2, 24 to 26%; CaO, 45 to 47%; Al_2O_3, Fe_2O_3 20 to 22%.

At Vitry, France, the slag is struck by a jet of water immediately upon issuing from the furnace and carried by it into a masonry storage tank. From this tank the granulated slag is elevated and carried to the mill. Five dryers of the style shown in Fig. 1 are employed, the dimensions being slightly different from those used at Choindez. After drying the slag is sieved, to remove the coarser particles, passed through six mills of different types, and again sieved. After having been thus reduced to the proper fineness, it is mixed with the slaked lime in ball mills operated discontinuously; the proportions being about 40 lb. lime to 100 lb. of slag.

Regulation of Set.—Slag cements set very slowly, relative to Portlands. As

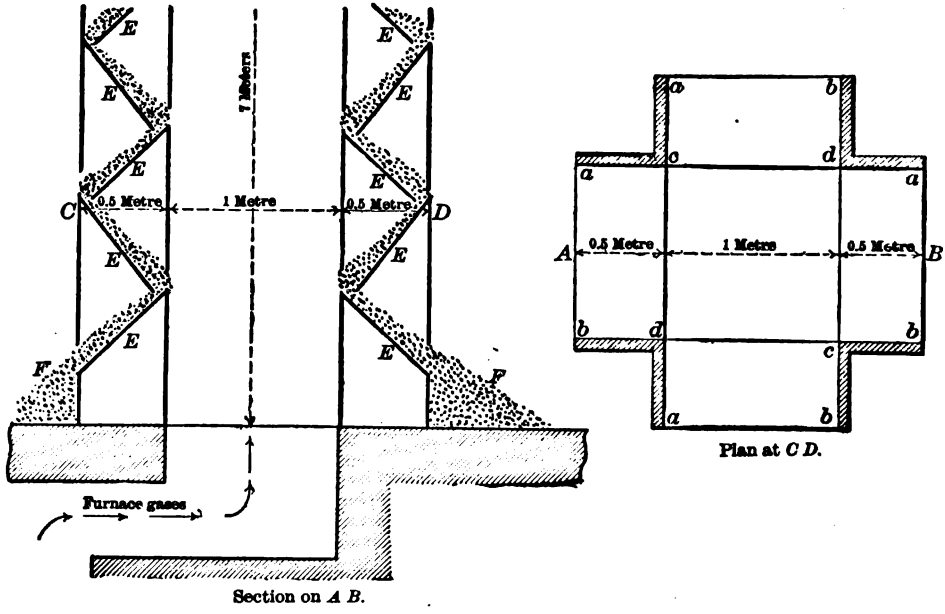

FIG. 1.—STATIONARY SLAG DRYER AT VITRY, FRANCE.

this interferes with their use for certain purposes, many attempts have been made, by various treatments, to reduce their setting time. There is, unfortunately, another reason why the manufacturer should desire to hasten the set of his product. Most of the slag cements sold in this country masquerade as Portland and it is desirable to the manufacturer therefore to make such of their properties as are brought out in ordinary tests or analyses approximate to those of true Portland cement. The set of slag cements can be hastened by the addition of pozzuolanic materials. Of these, burned clay, certain active forms of silica and slags high in alumina are the cheapest and most generally obtainable. The most important method of regulation is, in this country at least, the Whiting process, which is followed at two large American plants.

United States Patent No. 544,706, issued in 1895 to Jasper Whiting, covers

the use of "caustic soda, potash, sodium chloride, or equivalents or any substance of which the latter are ingredients," added either as aqueous solutions or in a dry state at any stage of the process of slag-cement manufacture. In the specifications accompanying the application for this patent, the patentee states that, in the case of dry caustic soda, the amount added will vary from 0·125 to 3%, "depending chiefly upon the use for which the cement is intended." The patent was subsequently conveyed to the Illinois Steel Co., and the process covered by it is used by that company in the manufacture of its "Steel Portland" cement. A license has been issued to the Brier Hill Iron and Coal Co., of Youngstown, Ohio, under which license this company manufactures its "Brier Hill Portland" cement.

The process, as practiced in the slag-cement plant of the Illinois Steel Co., Chicago, Ill., is as follows: The quicklime used is obtained from the calcination of Marblehead or Bedford limestone and carries less than 1% MgO. On its arrival at the mill it is unloaded into bins, beneath which are placed two screens of different mesh, the coarser at the top. A quantity of lime is drawn upon the upper screen, where it is slaked by means of the addition of water containing a small percentage of caustic soda. As the lime is slaked it falls through

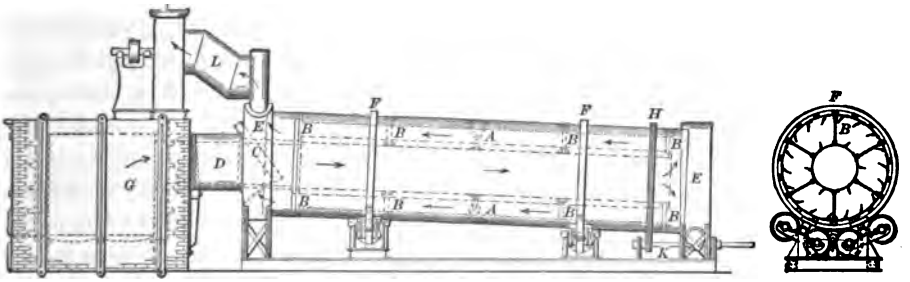

FIG. 2.—RUGGLES-COLES DRYER.

the coarse screen onto the finer screen, through which it falls into a conveyor which carries it to a rotary dryer. After heating, the resulting slaked and dried lime is carried by elevators to hoppers above the tube mills, where it is mixed in proper proportions with the granulated slag, which has been dried and powdered.

Drying.—The drying of the slag is one of the most important steps, economically, in slag-cement manufacture. The large percentage of water carried by granulated slag must be evaporated almost entirely, if good results are to be expected from the grinding machinery. Three types of dryers are used in common practice.

The Ruggles-Coles dryer (see Fig. 2) consists of two concentric hollow cylinders bolted together and revolving on an axis slightly inclined from the horizontal. The outer cylinder is made of steel plates, the longitudinal seams having butt joints with inside lapping straps. The inner cylinder, which is also made of steel, is connected with the outer cylinder at the center by heavy cast-iron arms, *A*, solidly riveted to both cylinders; and at each end, by two sets of adjustable or swinging arms, *B*, which prevent expansion and contraction from affecting the rivets or joints. At the head or upper end the inner cylinder

projects beyond the outer cylinder, passing into a stationary head or air chamber, *E*, to the hot air flue, *D*, of the furnace, *G*, with which it is connected. At the lower or discharge end is another stationary head, *E*, forming an air chamber, through an opening in the bottom of which the dried material is discharged. This head is provided with a damper to regulate the temperature which gives perfect control.

The outer cylinder is set at an inclination of about 0·375 in. to the foot. It is secured to two heavy rolled steel bearing rings, *F*, which rest and revolve upon eight bearing wheels supported by oscillating arms or rockers. The lateral motion of the cylinder is taken up by four thrust wheels. The dryer is revolved by a cast gear, *H*, secured to the outer cylinder, and this is driven by a shaft and pinion, *K*, extended beyond the end of the machine and supported in two babbitted journal boxes fitted to the frame. The entire machine is fitted and secured to a heavy frame of 8-in. "I" beams braced and framed together and usually set on a concrete foundation. The exhaust fan is placed where most convenient to drive and is connected with the outer cylinder by suitable flue, *L*. The furnace, *G*, is built independent of the machine and connected with the head end of the inner cylinder by an iron flue, *D*, built with fire brick. A specially designed burner is substituted for the furnace for the use of oil, gas, or powdered coal.

The heated air passes through the inner cylinder (shown by dotted lines in the illustration) and returns between the inner and outer cylinders to the fan. The direction of the hot air current also is shown by arrows. The slag is fed into the space between the inner and outer cylinders, through a spout *C*, in the stationary head at the upper end of the machine. It is picked up by buckets or carriers fastened to the inner surface of the outer cylinder and carried partly around during the rotation of the dryer. On dropping from these buckets it falls and is caught on the flights fastened to the outer surface of the inner cylinder, which carry it partly around and then drop it to the bottom of the outer cylinder, when the cycle commences again. While these movements of the slag are occurring, it is being dried both by the heated air in the space between the two cylinders and by contact with the warm outer surface of the inner cylinder; and it is also being carried slowly toward the lower (discharge) end of the machine.

The following table shows working results in the use of the Ruggles-Coles dryer on granulated slag:—

User.	Original Percentage Moisture.	Final Percentage Moisture.	Water Evaporated per Hour.	Dry Material Delivered per Hour.	Coal Used per Hour.	Water Evaporated per Lb. of Coal.
	%	%	Lb.	Lb.	Lb.	Lb.
Knickerbocker Cement Co.....	41·82	0·29	4,401	6,399	560	7·87
Maryland Cement Co.....	20·32	0·25	4,114	16,173	542	7·59
Birmingham Cement Co.....	45	....	4,181	4,967	537	7·60
Southern Cement Co.....	40	.....	4,707	7,061	550	8·56

The Holst dryer is used at Donjeux and Mallstadt, and consists essentially of a sheet-iron cylinder 9 m. long and 0·8 m. in diameter, into which the slag is fed automatically by a screw feed. In the cylinder a helical screw revolves on a hollow central shaft, causing the slag to advance slowly through the cylinder. The fireplace is below and near one end of the cylinder and the heat is caused

to pass under the cylinder to the other end; thence through the hollow shaft to the stack in a direction contrary to that in which the slag is moving. The cylinder is protected from the direct flame by brickwork. This apparatus dries from 7 to 8 metric tons of slag per day with a coal consumption of about 5% of the weight of slag dried.

At Vitry, France, a simple and effective non-rotary dryer, operated by gravity, is employed, plan and section of which is given in Fig. 1. It consists of drying compartments (each of which is lettered, *A,B,C,D,* in the plan) arranged about a central flue (*C,D,C,D,* in plan), through which passes the heated gases from a furnace. The central flue is 1 m. square; the drying compartments 0·5×1 m. in area; and both are 7 m. in height. Each of the drying compartments contains 10 sheet-iron plates (of which only six, *E,* are shown in each compartment of the section). These plates are inclined and so arranged that the wet slag, shoveled in at the top of each compartment, descends by gravity and finally issues from the lowest plate in the heaps, *F,* from which it is shoveled and sent to the grinding mills. According to Prost, a dryer of this type and size will dry from 12 to 15 metric tons of slag per working day. From 6 to 6·5 lb. of coke are necessary to dry each 100 lb. of slag.

Pulverizing and Mixing.—The greatest differences in practice exist in the processes for grinding and mixing the slag and lime. The statement has been made, in several publications, that the differences in hardness between dry granulated slag and slaked lime is so great that it is impracticable to pulverize them together in a continuously operated mill. A number of plants, therefore, have installed small discontinuous mills, each of which is charged, locked, operated for a sufficient time to pulverize both constituents of the mixture, and discharged. The disadvantage of this intermittent system are obvious and it seems especially unfitted for American conditions. The statement that no continuously operated mill was able to handle the mixture seemed inherently improbable, in view of the great variety of material successfully handled by the modern ball and tube mills when operated continuously in Portland cement practice. I referred the question to a leading firm of manufacturers and was informed that nothing in their experience justified the unfavorable conclusion; and that their continuously operated tube mills had successfully pulverized mixtures of slag and lime. It seems probable that the most economical practice would be to send the dried slag through a small crusher, Griffin mill or ball mill; mixing the crushed slag with lime, and completing the mixture and reduction in continuously operated tube mills. Whatever system of reduction is employed, it is necessary that the slag be dried as completely as possible and, with modern dryers, the amount of moisture in the dried slag can be economically kept well below 1%.

Identification of Slag Cement.—Slag cements may usually be distinguished from Portland cements by their lighter color, inferior specific gravity, and slower set. They show on analysis lower lime and higher alumina percentages than Portlands, and usually contain an appreciable amount of calcium sulphide. Owing to the presence of this last named constituent, a briquette of slag cement left for some days in water will show upon fracture a decided greenish tint; if

it has been exposed to salt water, this tint will be much more marked, and the odor of hydrogen sulphide will be observed. Two things should be noted, however, in this connection. The presence of sulphides though usual is not a necessary occurrence in slag cements; and, on the other hand, sulphides are occasionally present in Portland cements, being formed from the sulphates in case the flame of the kiln is not sufficiently oxidizing.

Color.—Slag cements are usually much lighter in color than the Portlands, varying from a bluish white to lilac. The color of the cement depends partly upon the color of the slag and the lime, but more largely upon the relative proportions of the two ingredients. Slag cements do not stain masonry, in which respect they have an advantage over Portlands for certain uses.

Specific Gravity.—Cements of this class are lighter than Portlands, their specific gravity usually ranging from 2·7 to 2·8. This gives a greater bulk for the weight, but on the other hand it reduces the density of the set cement, which is not desirable for some purposes.

Rapidity of Set.—Normally slag cements are slower setting than Portlands. Whether this property is a disadvantage or not will depend on the use to which the cement is to be applied. As before mentioned, the rapidity of set increases naturally with the amount of alumina in the slag. Set can be artificially hastened by the addition of pozzuolanic material to the cement; burned clay, certain active forms of silica, slags high in alumina, etc., are additions which are both effective and cheap. The treatment of the cement during manufacture with alkalies to accelerate the set, has already been discussed.

Strength.—While slag cements fall below high-grade Portlands in tensile strength, good American slag cements develop sufficient strength to pass the usual specifications for Portlands. Tested neat, they do not approximate so closely to the Portlands as they do if tested in 2:1 or 3:1 mortars. Part of this property may be due to the fact that they are, in general, ground finer than Portlands, especially than foreign Portlands. Prof. W. K. Hatt recently made a large series of tests on American slag cements, and reported that there was no noticeable deficiency in strength of briquettes kept in air as compared with those kept in water. Other investigators have arrived at opposite conclusions; and it is probable that these conflicting results arise from differences in the chemical composition of the various brands tested.

Resistance to Mechanical Wear.—Slag cements are notably deficient in this property, and are therefore not available for use for the surfaces of pavement, floors, etc., where this quality must be highly developed; they seem to be well fitted, however, for pavement foundations, or indeed for any work which will not be exposed to dry air, and in which a high strength is not necessary.

Plants.—Of the seven slag-cement factories now in operation in the United States, two each are located in Alabama and New Jersey, and one each in Illinois, Ohio and Pennsylvania. Two new plants are projected, and may be erected and in operation before 1903; these are to be located respectively in Alabama and Pennsylvania. Most of the plants now in operation are connected closely in ownership with the furnaces from which their slag is obtained. This condition is almost a necessity, since common ownership or control furnishes the only

possible guarantee that a sufficient supply of slag, of proper quality, will be always available.

Price.—The selling price of slag cements is highly variable, as can be understood from statements made on previous pages. Whenever possible, they are sold as Portlands; and in that case approximate in price to cements of that class. When necessary, however, they are marketed at prices below those of natural cement plants. Taking the entire annual product into consideration, its price per barrel will probably average about 20 to 25% higher than the best brands of natural cements (New York Rosendale). The industry affords very fair profits and the output in the United States is increasing steadily.

American slag cements are certainly superior in strength, uniformity and rapidity of set to European slag cements. Slag cements are not, however, Portland cements; and the sooner this fact is recognized and publicly admitted by their manufacturers, the better will be the prospects of the industry. For, though slag cements are entirely unfitted for many uses to which Portland cements may be applied, there are certain uses for which they are peculiarly well adapted, and if, for any particular use, a slag cement is as good as a Portland, its lower price will of necessity remove any danger of Portland competition.

CHROMIUM AND CHROME ORE.

THE production of chrome ore in the United States during 1901 was very small, although an advance on 1900, as that year produced none. The only mines in the country which were worked during the year being the California mines, which produced a total of 498 long tons, valued at $7,740. The imports of chrome ore during 1901 were 20,112 long tons, against 17,542 long tons during 1900, an increase of 2,570 tons during the year, the average value per ton being slightly higher in 1901 than in 1900—$18·05 and $17·39, respectively. The larger part of the chrome ore used in the United States is consumed in the manufacture of iron and steel products, for details of which reference may be had to the section devoted to "Iron and Steel" later in this volume. The consumption and demand for ferrochromium products were so disappointing during 1901 that several works formerly producing chrome steel and the alloys have altered their machinery for the manufacture of ferrotungsten and ferrotitanium as a substitute, because tungsten and titanium ores are more easily obtainable, both as to quantity and quality. The chrome ores for use in steel making are generally imported from Turkey. The total production of ferrochromium during 1901 was about 1,200 long tons, which commanded a smaller price than in 1900. Ferrochromium continues to be used chiefly in the manufacture of steel stamps, and while titanium steel has been substituted to some extent, it has not been very successful, owing to the difficulty of fusing titanium at the melting point of steel. The Willson Aluminum Co., of Kanawha Falls, W. Va., and Holcomb Rock, Va., makes an alloy of 50% Cr and 15% Ti, which has very great tensile strength as well as resistance to abrasion and shock. The use of chrome ore as a lining for furnaces has increased slightly during the year, and it is likely will continue to increase, for the life of such linings and bottoms is several times greater than any other known refractory material and its insertion is not difficult. In some instances the ore is made into bricks, but a very effective lining is produced by filling the spaces between the larger lumps of ore with the fines, tamping the whole to a fairly even surface.

The Chrome Steel Co., of Brooklyn, N. Y., early in 1902 determined to re-

move its plant to Cartaret, N. J., where a large universal forging machine of German design and manufacture will be installed.

PORDUCTION, IMPORTS AND CONSUMPTION OF CHROME ORE IN THE UNITED STATES.

Year.	Production.			Imports.			Consumption.	
	Quantity. Long Tons.	Value Per Ton.	Value.	Quantity. Long Tons.	Value Per Ton.	Value.	Quantity. Long Tons.	Value.
1897.....	150	$10·33	$1,550	11,566	$16·11	$186,318	11,716	$187,868
1898.....	100	10·00	1,000	16,304	16·70	272,234	16,404	273,234
1899.....	100	10·00	1,000	15,793	18·03	284,825	15,893	285,825
1900.....	*Nil.*	*Nil.*	*Nil.*	17,542	17·39	305,001	17,542	305,001
1901.....	498	15·54	7,740	20,112	18·05	363,108	20,610	368,898

California.—The total production of chromite in California during 1901 was 498 long tons, valued at $7,740, which was sold as crude product. The Shotgun Creek mine, in Shasta County, produced 130 long tons, valued at $1,950, while the Evans & Dougherty mine, of Dunsmuir, Siskiyou County, produced 368 long tons, valued at $5,790.

THE WORLD'S PRODUCTION OF CHROME ORE. (*a*) (IN METRIC TONS.)

Year.	Bosnia.	Canada.	Greece.	New Caledonia (*b*)	Newfoundland.	New South Wales.	Norway.	Russia.	Turkey. (*b*)	United States.
1896.....	443	2,124	1,600	16,018	1,031	3,914	*Nil.*	6,682	20,137	718
1897.....	396	2,392	563	9,054	3,084	3,433	*Nil.*	13,433	11,551	152
1898.....	458	1,833	1,367	14,300	657	2,145	*Nil.*	15,467	(*c*)	102
1899.....	200	1,796	4,386	12,480	717	5,327	41	19,146	*d* 4,536	102
1900.....	100	2,120	5,600	10,474	(*c*)	3,338	(*c*)	(*c*)	*e* 9,749	*Nil.*

(*a*) From the official statistics of the respective countries, except for the United States, which are our own. (*b*) Exports. (*c*) Statistics not yet published. (*d*) Exports from Salonica and Smyrna. (*e*) Exports from Salonica and Kossovo.

Canada.—The production of chrome ore during 1901—reported as exports during that year—amounted to 1,595 metric tons, valued at $25,444, against 2,120 metric tons, valued at $27,000 during 1900. The deposits of chrome ore in Coleraine, Province of Quebec, continue to furnish most of the product. The ore, consisting of chromic iron ore, is very easily mined, and is said to average 50% Cr_2O_3. No shipments have been made from the chrome deposits on Port au Port Bay, Newfoundland, for some time.

Greece.—The Bourdaly mines, at Thasala, 20 miles from the battlefield of Velstino in the Kassidiari ranges, produce annually about 3,000 tons of chrome iron ore, valued at 70 fr. per ton. The product is shipped mostly to Austria and utilized in the manufacture of ferrochromium. The mineral occurs in compact masses in a white or grayish colored earth in contact with serpentine, rarely with quartz or schist, and the ore analyzes Cr_2O_3 32·3%, FeO 41%, Al_2O_3 16%, ranges near the famous silver mines of Kissos, and deposits on Tinos Island SiO 8%. Chrome iron ore has also been discovered in Eubœa in the Pelion have been reported.

New Caledonia.—(By F. Danvers Power.)—Chromite when naturally broken up *in situ* is known in the trade as "alluvial chrome," and when massive it is termed "rock chrome." The alluvial variety is mostly sought, as being in separate grains it is not only easier to mine than the rock chrome, but requires no crush-

clay bottom under such conditions would have a life of little more than a week. A blister-copper furnace whose bridge-wall was constructed of chrome ore at about the same time as the smelting furnace, has shown no deterioration, and the author suggests the use of chrome ore as a lining for copper converters. The Selby Smelting & Lead Co., at Selby, Cal., has for years used a lining of California chrome iron ore, in crude lumps, wedged into shape with smaller particles and then cemented in weak spots with a mortar made of 10 parts of chrome iron ore to 1 part of plastic clay. This lining lasts for months while in use in copper matting and concentrating furnaces, and while weak spots develop owing to irregularities in the ore, they are patched, without much difficulty.

Geo. G. Blackwell, Sons & Co., Ltd., of Liverpool, England, claim to supply all furnaces in England and on the Continent with their special furnace lining, which is composed of chromium, magnesia, alumina and silica, and is said to be very refractory. The agent for the United States is the Harbison-Walker Co., of Pittsburg, Pa.

Chromite Bricks.—Chromite bricks as refractory material have found limited use only, owing to the fact that chrome iron ore shows a variable composition even when taken from a single mine, and also on account of their high cost. For the most refractory bricks no binding material is used except that which accompanies chromite in the form of impurities. In lower grade material, however, several binding mediums may be used, such as lime and clay or lime and bauxite in the proportions of 2% CaO and 25% clay or bauxite, a process covered by the United States Patent No. 578,351, 1901. A German Patent No. 71,067, 1900, has been issued for the use of gypsum and aluminum sulphate in the proportion of 2% of the former and 1% of the latter. This mixture is said to possess an advantage in that it gives plasticity to the mass, and also renders it but slightly more fusible, as when heated, the gypsum and aluminum sulphate are converted into CaO and Al_2O_3 with a consequent reduction in percentages to 0·85 and 0·15, respectively.

Electrolysis of Chrome Ores.—Metallic chromium is now being produced commercially at Essen, Germany, by the Goldschmidt aluminum reduction process. Several hundredweight of the metal made in a large crucible, occupies about half an hour for its reduction. The special value of metallic chromium in steel making is its freedom from carbon and by its use steels high in chromium and low in carbon can be manufactured. Ferrochromium, which has heretofore been used for this purpose, contains from 40 to 65% Cr and from 4 to 8% C, which precludes the manufacture of a low carbon chrome steel. In fact for a steel containing 2·5% Cr, metallic chromium must be used if the carbon in the steel is to be below 0·2%. In the manufacture of open-hearth steels, when ferrochromium is used the loss of chromium by oxidation amounts to about 25%; with metallic chromium, however, the loss is much smaller. The metal is most valuable in the manufacture of crucible steels of from 1 to 2% Cr content and for higher chrome products up to 10% Cr. Steels of even higher chromium percentage are now under experiment for the manufacture of special tools.

B. Neumann[1] obtained a good deposit of chromium on a carbon or metal

[1] *Zeitschrift fuer Elektrochemie*, 1901, 7 (48), 656-661.

cathode with a divided cell, containing a chromium salt at the cathode and an acid or saline solution at the anode. With chromic chloride solutions containing 10% Cr a current density of 0·9 ampere per sq. dm. gave chromic oxide only, while from 1·8 to 7·2 amperes gave a mixture of oxide and metal and from 9 to 18 amperes pure metal; under the last-named conditions current efficiency of 38% was obtained. The temperature seems to have but little effect on the current efficiency, but above 50°C. the metal is deposited as a black powder. A solution with 16% Cr yielded 57% efficiency, which was increased to 89·5% by changing the solution on the anode cell. With chromic sulphate the best conditions were from 6·7 to 8·5% Cr and a current density of from 13 to 23 amperes per sq. dm., giving an efficiency of from 84·6 to 86%. The acetate solution did not give as satisfactory results. The metallic deposits are of bright color and fairly lustrous but due to films of oxide it has a tendency to flake. The metal is hard, brittle and very pure, containing only 0·1 or 0·2% Fe. The decomposition potential of chromic sulphate of five times normal strength is 1·898 volts, while for chromic chloride of eight times normal strength it amounts to 1·685 volts. It is necessary, however, to use at least double these electromotive forces.

A number of patents have been applied for and granted during 1900 and 1901 in various countries of the world for new electrolytic and other ferrochromium processes. The Société Generale des Aciers Fins, of Paris, France, has obtained French Patent No. 6,655, of 1901, for a method of making chrome steel in the open-hearth furnace. P. Straneo[2] confirms by experiment the claims made in the patents of Street, that a quicksilver electrode gives better results than a platinum one, when used for the electrolytic reduction of chromium oxides and salts.

The Chemische Fabrik Griesheim Electron, of Frankfort-on-Main, Germany, obtained German Patent No. 12,250, of 1901, for the production of chromium compounds and alkali by the electrolysis of salts of alkali with ferrochrome anodes. William H. Greene and William H. Wahl, of Philadelphia, Pa., obtained United States Patent No. 688,510, of December 10, 1901, for a method of producing chromium, which consists in incorporating silicides with metallic oxides, the heat of formation of which is less than that of the oxides of either element of the silicides, and subjecting the mass to heat, and thereby effecting the primary reduction of the oxides by the chemical energy of both elements of the silicides.

A novel form of electric furnace was patented by Charles A. Keller, of Paris, France, on December 17, 1901. The electrodes are trucks mounted on rails, and each adjustable toward a central horizontal fire brick hearth which carries the main body of the charge. The electrode carriages are framed in iron, covered by a fire brick arch which bears the carbon or outer surface of the electrode. The central horizontal hearth, and the upwardly inclined lateral electrodes together form a broad, shallow furnace bed, over which a layer of granular carbon is spread to serve as a circuit closer between the electrodes, and by its resistance

[2] *L'Elettricita*, 20, 40, S. 627, 1901.

to develop a temperature sufficient for the reaction. Any resistance material may be substituted for this if the carbon should prove undesirable. For the production of chrome iron a bed of granular iron may be used which would alloy with the chrome as reduced. The furnace proper is inclosed within a fire brick vault to preserve the heat and exclude the air.

M. Armengand, Jr., of Paris, has secured by French Patent No. 301,804, of July 5, 1900, a process for the manufacture of mild ferrochromium in the electric furnace, which will contain Cr 60%, Fe 29 to 39%, and C 1%. The product is magnetic, tough, comparatively soft, and may be drilled by steel, characteristics which distinguish it from ordinary ferrochromium.

Bichromates and Other Salts.—Dr. Berthold Redlich, of Berlin, Germany, manufactures chrome yellow by electrolyzing lead hydroxide, which is obtained by exposing lead anodes to the action of an electric current, in a nitrate or acetate electrolyte. The resulting hydroxide precipitated from its solution by means of an alkali, reacts directly and in the cold on chromates or bichromates. The physical characteristics of the hydroxide may be transmitted to the product, and either a flocculent or crystalline chrome yellow produced by using a concentrated cold solution or a warm dilute solution. The alkali salts employed as electrolytes furnish the alkali used to precipitate the lead hydroxide. If no free acid be used in the subsequent chrome admixture, orange chrome is produced, free acid being necessarily present for the production of the lemon shades. The process is said to be much cheaper than the former practice.

A. Shearer, of Manchester, England, in the latter part of 1900 secured English Patent No. 14,021 for improvements in the manufacture of sodium and ammonium chromates.

CHEMISTRY.

Review of Analytical Chemistry.—(By Edmund H. Miller.)—J. Feree[1] states that metallic chromium is readily deposited on a platinum cathode from a solution of crystalline chromic chloride acidified with hydrochloric acid, steel gray in color; while from a solution containing chromic and potassium chlorides in the proportion of $CrCl_3$ to 3KCl, it comes down as a silver white metal. The current used was 8 volts and 15 amperes per 100 sq. cm. of cathode area.

C. Reichard,[2] in an article on the recognition of chromic acid by hydrogen peroxide, calls attention to the following difficulties: (1) Vanadic acid exercises a remarkable influence on the perchromic acid reaction, by giving a brownish color which interferes with the clear blue of the perchromic acid. This is noticeable when the vanadium is present in the proportions of one part of ammonium metavanadate to 10 parts of potassium dichromate.

(2) That both arsenate and phosphate of sodium counteract the disturbing influence of vanadic acid on the reaction; while other salts, such as $NaNO_3NaNO_2$, $(NH_4)_2S_2O_8$,$KIO_3NO_2(NO_3)_2$ have no influence.

(3) That molybdic and tungstic acids appear to influence the reaction similarly to vanadic acid.

[1] *Bulletin Société Chemique*, 25, 617.

[2] *Zeitschrift fuer Analytische Chemie*, 40, 577.

R. Hartmann[3] describes an application of the ordinary volumetric method for chromium, by estimating the oxidizing power of the chromic acid, to the determination of chromium oxide in mordants. This method should prove most acceptable and is a valuable improvement to the tedious gravimetric methods which have been used. It is in brief as follows: About 1 g. of the chromic acetate (about 21°B.) is diluted with from 10 to 15 c.c. of water and a little strong caustic soda solution is added until the precipitate dissolves. The solution is heated on a water bath and sodium peroxide is added until the solution is yellow and the oxidation to sodium chromate complete; then evaporated to dryness to decompose any excess of peroxide, redissolved in 500 c.c. of water, and acidified with dilute sulphuric acid. 50 c.c. of N/10 solution of Mohr's salt ($FeSO_4(NH_4)_2SO_46H_2O$) are added and after diluting to a liter the excess of ferrous iron is titrated by N/10 potassium permanganate, to a dirty violet color. The chromium is calculated from the amount of Mohr's salt it oxidizes on the bases of 1 Cr=3Fe.

[3] *Chemiker Zeitung*, July 8, 1901, p. 564.

CLAY.

THE production of clay products in the United States during 1901 increased considerably over the output of the preceding year, the aggregate value being $87,747,727, as compared with $78,704,678 in 1900. The chief cause of the increased output was the great prosperity in the building trades, which is reflected in the very large increase in the production of building brick. The drain tile trade, however, suffered materially from the drought in the central West. At the beginning of the season the demand was so great that almost a brick famine resulted in many places, manufacturers frequently being compelled to refuse further orders. Despite the increased demand for bricks lower prices ruled, which resulted ultimately to the benefit of the trade, as thereby considerable competition was prevented, both for the present and for the future. The number of firms reporting brick and tile products during 1901 was 5,887.

The production of clay and clay materials in the United States is summarized in the following table:—

PRODUCTION OF BRICK AND CLAY WARES IN 1900 AND 1901.

Kind.	1900.			1901.		
	No. of M.	Value.	Per M.	No. of M.	Value.	Per M.
Common brick	7,500,868	$39,195,913	$5·23	8,088,579	$45,508,076	.....
Front brick	455,771	4,601,686	10·09	415,343	4,709,737	.....
Fire brick (a)	372,385	5,823,208	15·64	.....	9,870,421	.....
Paving and vitrified brick	724,370	6,503,442	8·97	.....	5,484,134	.....
Other clay building material (b)	.....	5,530,369	.....	(f)	.....	.....
Sewer pipe and drain tile	.....	e 8,550,000	.....	.....	6,736,969	.....
Crude clay, stoneware and misc. man'f'res (c)	.....	e 8,500,000	.....	.....	15,443,390	.....
Totals	.....	$78,704,678	....	.....	$87,747,727	.....

(a) Not including silica brick. (b) Including terra cotta lumber, hollow building tile or blocks, roofing tile, floor tile and all other clay building material. (c) Including the value of common stoneware and various miscellaneous clay manufactures and crud clay used in pottery, for laying fire brick, in paper making, as burnt clay railway ballast, for the manufacture of gas retorts, glass pots, zinc retorts, etc. (e) Estimated. (f) Included under crude clay, etc.

The collection of these statistics is attended with many difficulties. In no other branch of the mineral industry except that of stone is the number of producers so large and so widely distributed. Most of them operate on a small scale, and as but little outlay of time and capital is required to open a brickyard,

PRODUCTION OF BRICK AND CLAY BUILDING MATERIAL IN THE UNITED STATES IN 1900. (IN THOUSANDS.)

States.	Building Brick. Common.		Building Brick. Front.		Fire Brick. Alumina.		Paving Brick.		Other Clay Building Material.
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Value.
Alabama	50,700	$294,060	.....	.....	e 6,760	$141,960	.....	.....	e $1,000
Arizona (e)	10,000	70,000	125	$1,750	.....	.....	.....	.....	.....
Arkansas	45,000	281,250	e 5,000	55,000	.....	.....	.....	.....	.....
California (e)	130,000	650,000	3,000	60,000	.....	.....	.....	.....	.....
Colorado	42,520	245,980	21,296	222,818	2,092	35,563	1,338	$13,381	754
Connecticut	141,381	709,403	7,000	63,000	.....	.....	.....	.....	65,000
Delaware	13,650	87,019	2,625	26,250	.....	.....	.....	.....	.....
Dist. of Columbia	90,000	760,000	3,150	56,400	.....	.....	.....	.....	.....
Florida	35,120	210,000	.....	.....	.....	.....	.....	.....	.....
Georgia	199,043	977,960	4,874	58,469	e 2,200	26,400	4,861	17,043	e 65,000
Idaho	18,107	129,804	.....	.....	.....	.....	.....	.....	.....
Illinois	476,350	2,581,817	17,003	87,856	9,519	81,078	190,156	1,639,191	784,743
Indiana	392,390	2,126,374	15,123	138,351	3,762	37,622	65,921	662,321	e 350,000
Indian Territory	4,000	20,000	500	5,000	.....	.....	.....	.....	.....
Iowa	244,804	1,494,868	11,409	101,287	206	2,361	30,002	220,455	60,526
Kansas (e)	50,000	300,000	8,000	60,000	700	6,300	30,000	240,000	.....
Kentucky	123,641	666,456	6,500	39,000	28,000	290,000	3,000	18,000	130,000
Louisiana	114,285	338,915	9,600	76,800	.....	.....	5,000	30,000	5,000
Maine	115,000	618,700	2,325	18,800	.....	.....	150	1,200	.....
Maryland	288,517	1,451,479	9,614	204,791	6,495	101,888	144	1,299	60,000
Massachusetts	305,415	1,573,478	75,850	918,700	6,000	95,000	.....	.....	75,000
Michigan	204,081	960,254	3,858	26,758	.....	.....	4,000	36,000	e 8,000
Minnesota	211,628	1,074,715	9,234	92,525	114	2,286	.....	.....	31,544
Mississippi	48,164	263,110	712	5,435	.....	.....	5,176	31,059	.....
Missouri	225,000	867,500	20,000	125,000	14,594	179,607	24,721	197,908	e 300,000
Montana	43,018	240,444	78	1,163	2,000	50,000	350	15,000	.....
Nebraska	108,512	643,227	3,810	30,476	.....	.....	5,714	40,524	.....
New Hampshire	63,484	335,278	6,490	67,850	1,180	23,600	944	8,496	.....
New Jersey	355,047	1,485,028	35,000	600,000	30,000	600,000	300	3,000	e 2,000,000
New Mexico	2,000	14,000	1,300	10,400	250	2,500	.....	.....	.....
New York	1,120,000	4,849,600	30,000	240,000	e 20,000	400,000	35,000	420,000	650,000
North Carolina	102,060	516,537	206	2,057	57	1,143	100	800	1,500
North Dakota	42,196	257,550	1,063	11,375	350	6,300	1,500	35,000	300
Ohio	522,949	3,082,783	66,359	129,896	105,779	2,114,582	e 200,000	1,800,000	e 375,000
Oklahoma	12,581	84,279	.....	.....	.....	.....	.....	.....	.....
Oregon	14,732	104,539	188	5,288	5	84	.....	.....	.....
Pennsylvania	797,681	5,246,237	61,998	663,946	100,774	1,606,218	68,887	589,881	e 500,000
Rhode Island (e)	40,000	210,000	1,500	13,500	.....	.....	5,000	45,000	15,000
South Carolina	142,837	652,781	904	9,047	e 600	6,000	500	2,500	.....
South Dakota	16,286	131,571	157	5,143	.....	.....	150	1,500	.....
Tennessee	126,768	650,983	3,048	30,479	48	481	e 12,000	170,000	e 2,000
Texas	141,340	838,092	5,799	63,143	500	7,500	2,767	24,800	.....
Utah	40,903	227,645	5,607	60,587	.....	.....	.....	.....	.....
Vermont	42,257	194,827	14,571	65,571	.....	.....	.....	.....	.....
Virginia	77,398	430,017	1,290	15,382	.....	.....	1,346	12,789	e 45,000
Washington	61,234	471,682	3,400	68,000	.....	.....	350	6,300	.....
West Virginia	23,012	116,417	1,750	21,000	e 400	4,800	e 25,000	220,000	e 5,000
Wisconsin	122,727	755,794	4,480	33,630	.....	.....	.....	.....	.....
Wyoming	e 300	2,700	.....	.....	.....	.....	.....	.....	.....
Totals	7,500,868	$39,195,913	455,771	$4,601,686	372,395	$5,823,268	724,370	$6,503,442	$5,580,369

its abandonment is of no serious consideration. The list of producers consequently is subject to continuous revision. A further difficulty arises from the fact that some concerns do not keep any records of their work, and are therefore not in position to furnish accurate reports.

The production of brick and clay building material by States in 1900 and 1901 is presented in the above tables, in which the columns "common brick" include only the ordinary red brick that is used generally in building. Under "front brick" we have grouped pressed brick of all colors. Under "fire brick," however, only what is properly termed alumina brick is included. Such silica brick as Dinas brick, which is also properly called "fire brick" or "refractory brick" being omitted, because it is not a clay product. "Other clay material" includes fancy or ornamental and enameled brick, roofing tile, terra cotta, terra cotta lumber, floor tile, hollow building blocks, etc. All the clay material other

PRODUCTION OF BRICK AND CLAY BUILDING MATERIAL IN THE UNITED STATES IN 1901. (IN THOUSANDS.)

States.	Building Brick. Common.		Building Brick. Front.		Fire Brick. Alumina.	Paving Brick.	Sewer Pipe.	Other Clay Building Material.	Total Value.
	Quantity.	Value.	Quantity.	Value.	Value.	Value.	Value.	Value. (e)	
	Thous.		Thous.						
Alabama	128,914	$742,691	795	$6,990	$182,783	(a)	.....	ƒ $1,800	$933,429
Arizona	13,533	92,986	.....	.....	.....	.....	.....	.....	92,986
Arkansas	56,501	368,359	1,205	11,570	18,580	(a)	.....	ƒ 950	395,858
California	146,522	943,250	8,787	86,425	87,665	(a)	$285,599	ƒ 279,692	1,785,721
Colorado	116,160	760,867	16,563	196,147	292,269	(a)	(a)	ƒ 170,965	1,568,167
Connecticut and Rhode Island	160,606	822,079	(a)	(a)	(a)	.....	.....	ƒ 109,500	1,039,709
Delaware	15,968	126,092	(a)	(a)	.....	.....	.....	(ƒ)	131,164
Dist. of Columbia	23,175	179,184	(a)	(a)	.....	.....	95,000	ƒ 134,652	311,129
Florida	32,253	185,759	(a)	(a)	.....	.....	(a)	8,015	190,674
Georgia	222,111	1,182,553	5,325	55,700	35,000	(a)	151,500	ƒ 85,480	1,527,853
Idaho	8,391	66,514	(a)	(a)	.....	.....	.....	ƒ 272	66,786
Illinois	930,561	5,188,654	19,241	204,080	212,510	$899,454	348,716	ƒ 2,040,851	8 960,041
Indiana	315,966	1,624,133	27,293	234,775	51,520	320,221	253,026	1,400,402	3,985,083
Indian Territory	17,603	110,774	(a)	(a)	(a)	.....	.....	.....	117,224
Iowa	349,318	1,611,040	8,785	88,164	1,810	241,108	54,500	714,583	2,711,305
Kansas	108,365	555,928	5,495	50,340	(a)	312,994	(a)	ƒ 43,300	961,090
Kentucky	115,977	621,756	2,486	16,535	377,741	(a)	100,705	ƒ 23,498	1,374,846
Louisiana	94,981	560,375	(a)	(a)	.....	.....	.....	ƒ 27,220	612,595
Maine	69,819	407,354	2,530	22,350	(a)	(a)	(a)	3,880	734,678
Maryland	113,457	676,708	5,772	76,792	342,055	(a)	(a)	ƒ 82,811	1,273,175
Massachusetts	170,455	1,060,493	6,950	98,892	57,945	.....	.....	ƒ 211,911	1,589,489
Michigan	215,836	1,095,254	9,476	64,031	.....	(a)	(a)	ƒ 101,489	1,497,169
Minnesota	157,727	852,303	5,506	55,016	(a)	.....	(a)	ƒ 43,089	1,256,552
Mississippi	76,716	443,939	650	6,455	.....	.....	.....	(ƒ)	451,694
Missouri	276,821	1,595,031	26,301	298,158	620,116	325,247	788,513	818,701	4,409,906
Montana	51,739	357,210	1,248	18,432	152,650	.....	(a)	ƒ 2,530	530,221
Nebraska	109,060	668,863	6,806	85,260	.....	28,150	.....	11,700	806,473
Nevada	2,020	16,425	(a)	(a)	.....	.....	.....	.....	17,025
New Hampshire	114,532	741,589	(a)	(a)	(a)	.....	.....	.....	765,964
New Jersey	351,886	1,675,746	29,239	473,138	780,827	23,024	(a)	ƒ 2,510,092	5,781,805
New Mexico	9,885	72,045	(a)	(a)	.....	(a)	.....	(ƒ)	81,345
New York	1,016,237	4,947,599	18,721	254,696	293,944	343,343	96,770	ƒ 1,278,988	7,214,358
North Carolina	132,699	682,469	990	8,070	3,720	(a)	(a)	ƒ 10,042	751,301
North Dakota	10,948	60,508	(a)	(a)	(a)	.....	.....	.....	76,708
Ohio	480,275	2,725,512	69,405	612,718	1,287,059	1,443,537	2,785,703	ƒ 2,709,601	11,526,434
Oklahoma	28,137	196,735	875	7,850	(a)	.....	.....	(ƒ)	205,060
Oregon (b)	23,422	172,058	354	8,469	962	.....	(a)	ƒ 12,179	963,891
Pennsylvania	875,631	5,357,079	70,207	844,067	4,791,083	670,081	488,998	1,490,315	13,656,730
South Carolina	144,601	546,028	168	1,188	14,925	.....	.....	ƒ 250	563,346
South Dakota	7,235	54,365	(a)	(a)	(a)	.....	.....	.....	59,365
Tennessee	92,502	610,968	3,073	32,350	37,100	67,129	(a)	ƒ 15,961	829,874
Texas	222,459	1,396,889	10,188	95,492	28,337	(a)	(a)	ƒ 11,971	1,532,189
Utah	23,262	134,164	17,490	139,591	5,100	.....	(a)	ƒ 1,834	291,189
Vermont	11,872	61,554	.....	.....	.....	.....	.....	16,000	77,554
Virginia	171,624	1,189,894	17,650	267,028	8,971	.....	.....	24,407	1,435,300
Washington	61,595	477,960	6,995	147,881	24,542	189,162	118,584	ƒ 3,848	927,398
West Virginia	60,004	348,452	(a)	(a)	102,300	555,389	(a)	ƒ 3,985	1,067,838
Wisconsin	187,178	1,151,898	6,527	54,374	(a)	(a)	.....	ƒ 26,282	1,234,144
Wyoming	2,960	24,050	(c)	(c)	.....	.....	.....	4,900	28,950
Other States (d)	.....	.....	7,297	85,788	124,401	216,295	1,268,755	641,561	(ƒ)
Total	8,038,579	$45,503,076	415,343	4,709,737	9,870,421	$5,484,134	$6,736,969	$15,443,390	$87,747,727
Per cent. of brick and tile products	.....	51·86	.....	5·37	11·25	6·25	7·68	.....	100·00
Per cent. of total of clay products.	.....	41·29	.....	4·27	8·96	4·98	6 11	.....	79·62

(a) Included in "Other States." (b) Includes Hawaii. (c) Value of front brick for Wyoming included in other clay building material. (d) Includes all products made by less than three producers in one State, in order that the operations of individual establishments may not be disclosed. (e) Fancy and ornamental brick, stove linings, drain tile, ornamental terra cotta, fireproofing, ordinary tile, including adobes, assayers' supplies, boiler and locomotive tile and tank blocks, building blocks, burnt clay ballast, chemical brick, patent chimney brick, chimney pipe and tops, clay furnaces and retorts, conduit for underground wires, crucibles, cupola brick, fence posts and stubs, fire clay mortar, flue linings, frost-proof cellar brick, furnace mantels, gas logs and settings, glass-melting pots and glass-house furnace blocks, grave markers, hollow bricks, muffles, supports and slides, porous cups, runner brick, sidewalk tile, souvenirs, stone pumps, terra-cotta vases, vitrified sewer brick, wall coping, water pipe, and well brick and tile. (ƒ) Partly included in "Other States."

than brick, which is now used so extensively in the construction of fireproof buildings is included under this classification. A slightly different classification has been adopted for 1901, which is fully explained in the individual headings of the columns and in the appended foot notes.

VALUE OF THE PRODUCTS OF CLAY IN THE UNITED STATES IN 1900 AND 1901.

State.	1900.			1901.		
	Brick and Tile.	Pottery.	Total.	Brick and Tile.	Pottery.	Total.
Alabama	$692,481	$20,296	$712,727	$928,429	$18,362	$946,791
Arizona	112,737	.....	112,737	92,986	.....	92,986
Arkansas	354,732	26,280	381,012	395,858	11,405	407,263
California	1,351,611	24,297	1,375,908	1,735,721	33,434	1,769,155
Colorado	1,182,575	*a* 17,944	1,200,519	1,568,167	26,700	1,594,867
Connecticut and Rhode Island	1,038,722	61,250	1,099,972	1,039,709	*k* 91,200	1,130,909
Delaware	156,274	.....	156,274	131,164	.....	131,164
District of Columbia	278,080	10,873	288,953	311,129	12,879	324,008
Florida	140,604	(*b*)	140,604	190,674	(*b*)	190,674
Georgia	1,168,835	*b* 24,383	1,193,218	1,527,853	17,280	1,545,083
Hawaii	.....	.....	.....	(*l*)	.....	(*l*)
Idaho	49,382	(*a*)	49,382	68,328	.....	68,328
Illinois	6,932,086	776,773	7,708,859	8,960,041	682,449	9,642,490
Indiana	3,532,450	*c* 325,900	3,858,350	3,935,083	531,371	4,466,454
Indian Territory	80,233	.....	80,233	117,224	.....	117,224
Iowa	2,254,662	36,589	2,291,251	2,711,305	26,520	2,737,825
Kansas	1,002,689	14,061	1,016,750	981,020	(*m*)	981,020
Kentucky	1,349,827	131,497	1,481,324	1,374,846	139,697	1,514,543
Louisiana	503,394	4,300	507,694	612,595	3,108	615,703
Maine	724,934	(*d*)	724,934	734,678	(*m*)	734,678
Maryland	1,275,239	496,617	1,771,856	1,272,175	333,480	1,605,655
Massachusetts	1,594,377	*d* 238,724	1,833,101	1,589,469	281,368	1,870,837
Michigan	1,147,378	34,317	1,181,695	1,497,169	44,865	1,542,034
Minnesota	1,103,302	*e* 293,395	1,396,697	1,250,552	292,095	1,548,647
Mississippi	558,916	14,452	573,368	451,694	4,779	456,473
Missouri	3,665,093	71,474	3,736,567	4,409,906	64,647	4,474,553
Montana	350,489	(*a*)	350,489	539,221	(*m*)	539,221
Nebraska	683,958	.....	683,958	806,473	.....	806,473
Nevada	9,580	.....	9,580	17,625	.....	17,625
New Hampshire	485,013	(*f*)	485,013	765,964	(*m*)	765,964
New Jersey	5,664,772	*f* 5,263,651	10,928,423	5,781,805	5,900,073	11,681,878
New Mexico	41,898	.....	41,898	81,345	.....	81,345
New York	6,496,281	*g* 1,166,325	7,660,606	7,214,358	1,077,360	8,291,718
North Carolina	797,112	18,863	815,975	751,301	20,087	771,388
North Dakota	92,399	.....	92,399	76,708	.....	76,708
Ohio	9,731,305	*h* 8,573,323	18,304,628	11,526,424	10,048,561	21,574,985
Oklahoma	164,457	.....	164,457	205,060	.....	205,060
Oregon	284,095	17,290	281,385	*n* 263,891	(*m*)	*n* 263,891
Pennsylvania	12,000,875	1,390,873	13,391,748	13,656,730	1,665,012	15,321,742
Rhode Island	(*i*)	.....	.....	(*i*)	.....	(*i*)
South Carolina	693,708	17,628	711,336	563,346	11,872	575,218
South Dakota	43,440	.....	43,440	59,365	.....	59,365
Tennessee	865,923	49,655	915,578	829,874	64,093	893,967
Texas	1,063,553	87,464	1,171,017	1,632,189	91,186	1,723,375
Utah	227,621	6,600	234,221	291,189	(*m*)	291,189
Vermont	121,041	.....	121,041	77,554	.....	77,554
Virginia	1,302,085	3,110	1,305,195	1,435,300	4,047	1,439,347
Washington	616,029	9,430	625,459	927,298	17,500	944,798
West Virginia	1,384,924	631,841	2,016,765	1,087,688	856,642	1,946,480
Wisconsin	1,072,179	(*e*)	1,072,179	1,234,144	13,400	1,247,544
Wyoming	21,500	.....	21,500	28,950	.....	28,950
Other States	.....	.....	.....	.....	*o* 76,488	*o* 76,488
Total	$76,413,775	$19,798,570	$96,212,345	$87,747,727	$22,463,860	$110,211,587
Per cent. of total	79·42	20·58	100·00	79·62	20·38	100·00

(*a*) Value of the pottery products of Idaho and Montana is included with that of Colorado. (*b*) Value of the pottery products of Florida is included with that of Georgia. (*c*) Porcelain electrical supplies for Indiana included in New York. (*d*) Value of the pottery products of Maine is included with that of Massachusetts. (*e*) Value of the pottery products of Wisconsin is included with that of Minnesota. (*f*) Value of pottery products of New Hampshire is included with that of New Jersey. (*g*) Includes porcelain electrical supplies for Indiana and china for Ohio. (*h*) China for Ohio included in New York. (*i*) Included with Connecticut. (*k*) Produced by Connecticut alone. (*l*) Included in Oregon. (*m*) Included in "Other States." (*n*) Includes Hawaii. (*o*) Comprising pottery totals for the following States: Florida, Kansas, Maine, Montana, New Hampshire, Oregon and Utah. This total could not be distributed among the States to which it belongs without disclosing the operations of individual establishments.

As an exponent of the increasing use of burned clay products as a building material may be cited the number of building permits issued, together with the buildings erected under these permits in 42 of the principal cities of the United States for the past two years. In 1900 there were 68,417 permits affecting buildings valued at $241,516,585, as compared with 85,571 permits affecting buildings valued at $372,173,631 in 1901, an increase in number of 25% and of over 50% in value.

Fire Clays and Their Manufacture into Refractory Materials.

By Heinrich Ries.

Raw Materials.—The individual clays used in the manufacture of refractory goods show as much variation in their physical and chemical characters as those employed in the making of any other high-grade clay product, and the fact that a clay is used in making fire brick or other refractory ware does not necessarily mean that it is of refractory character; indeed some of the clays used are of a low order of refractoriness, but these are seldom added to the mixture in large quantities, being employed in small amounts because of some special physical character, such as high plasticity, or density after burning.

It would be almost impossible to give a definition of the name fire clay which would include everything that is put on the market, for many materials are called refractory which have very low fire-resisting qualities; but it seems desirable that the term should properly be restricted to include only those clays which are able to withstand a high temperature, although this character alone does not always adapt them to the manufacture of refractory wares. In the United States a standard of refractoriness has never been adopted, but a clay should not be considered refractory unless its fusing point lies above 2,700°F. The degree of plasticity, air-shrinkage, fire-shrinkage, texture and color, are exceedingly variable in clays of high refractoriness and consequently these physical properties cannot be specified in the definition.

Color.—Fire clays vary greatly in color, being frequently bluish gray, gray, or black, due to the presence of organic matter. The reason for this is that many fire-clay deposits are intimately associated with coal-beds, and derive their carbonaceous coloring material from the organic matter which accumulated in the swamps in which the coal-forming plants grew. Many refractory clays, however, do not contain this finely disseminated organic matter, and in these cases the color may be buff, white, yellowish, or pink, its shade and density varying with the amount and form of iron which the clay contains. Some of the New Jersey clays are mottled red and light buff, red and white, or yellow and white, owing to the fact that the iron oxide is not evenly distributed throughout the mass.

Hardness.—There is considerable variation in the hardness of clay due to the conditions under which it has been formed. Many of the Carboniferous fire clays buried under thousands of feet of other sediments have been transformed to shale by pressure, while others formed in more recent geological times, and covered since their formation by less sediment have not been hardened, but have retained their soft plastic condition and can be easily dug by pick and shovel. The Cretaceous and Tertiary fire clays in New Jersey and other portions of the Atlantic coastal region are of this class. The shale clays, although seemingly hard and non-moldable, will generally yield a plastic mass on being ground and mixed with water. For this reason shale fire clays and soft fire clays are grouped together, forming the "plastic" fire clays, to distinguish them from the "flint" clays, which are hard, dense, fine-grained, of variable color, sometimes very slight luster, and conchoidal fracture. The latter usually occur in beds, interstratified with other rocks similar in origin to the shale clays with which

they may sometimes occur in the same bed. On grinding and mixing with water flint clays develop little or no plasticity, even though they may approximate plastic clays in composition.

Texture.—The same differences in texture exist in refractory clays as in other grades; some are very coarse and sandy, showing large angular particles of quartz, while others are exceedingly fine and show little or no grit. This fineness may have more or less effect on the fusibility of the clay, as will be mentioned later.

Fusibility and Composition.—The refractoriness of a fire clay depends chiefly on the chemical composition and partly on the fineness of grain. Analysis shows that they contain the same components as other clays, but in slightly different proportions.

The percentage of fluxes, *i.e.*, ferric oxide, lime, magnesia and alkalies, is usually quite low, as is evident from the analyses of a number of different fire clays given in the subjoined table:—

Specimens.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	Alkalies.	Moisture.	H_2O.	Miscellaneous.	
1.....	74·28	17·25	1·19	0·40	Trace.	0·52	.....	6·30	.....	.....
2.....	59·98	30·29	0·27	0·28	.....	1·02	8·05		.....	.....
3.....	50·350	33·64	0·75	.....	Trace.	0·58	.....	11·75	TiO_2 0·80	.....
4.....	46·17	39·13	0·45	0·18	0·11	1·14	0·51	$\{CO_2$ 13·06$\}$	.....	.....
5.....	73·32	16·06	1·1	0·7	0·7	.....	8·12		.....	.....
6.....	63·00	23·57	1·87	0·44	0·89	2·69	.....	6·45	FeO 0·46	TiO_2 1·1
7.....	73·24	15·76	1·93	0·325	0·379	1·614	6·629		.....	.....
8.....	47·2	39·9	.....	Trace.	Trace.	0·21	12·69		.....	.....
9.....	44·395	38·558	.....	Trace.	0·108	0·247	.....	14·575	FeO 1·08	TiO_2 1·58
10.....	61·73	23·56	5·16	0·55	0·15	1·00	2·94	9·25	SO_3 0·56	TiO_2 0·96
11.....	61·408	25·551	0·281	1·32	1·43	0·89	.....	9·75	.....	.....
12.....	61·6	28·38	0·52	0·46	0·36	.....	5·08		.....	TiO_2 3·6
13.....	46·9	35·9	1·1	.....	.....	0·44	1·5	12·8	.....	TiO_2 1·3
14.....	47·4	39·01	0·15	Trace.	Trace.	Trace.	.....	14·1	.....	.....
15.....	68·28	18·88	2·60	0·70	0·18	2·29	0·76	6·47	.....	TiO_2 0·27
16.....	52·52	31·84	0·67	0·50	0·19	0·59	0·69	11·68	.....	TiO_2 1·68
17.....	58·78	26·47	1·23	0·59	0·32	0·99	1·04	9·96	.....	TiO_2 0·94
18.....	44·05	37·51	.....	0·49	0·181	0·065	15·21		FeO 0·819	.....
19.....	43·46	41·61	1·03	0·24	0·09	.....	13·29		.....	.....
20.....	84·42	9·41	1·07	Trace.	0·39	.....	3·42		.....	.....
21.....	68·55	26·00	Trace.	Trace.	0·11	Trace.	6·00		.....	.....
22.....	68·315	19·62	1·575	0·1	0·692	2·704	5·58		.....	.....

1. Bibbville, Bibb Co., Ala. 2. Carbondale, Amador Co., Cal.; washed. 3. Denver Fire Clay Co., mines at Golden, Colo. 4. Van Buren property, Griswoldville, Ga. 5. Leatherwood Co., half mile from Bloomingdale, Parke, Co., Ind. 6. S. L. McCune, Mecca, Parke Co., Ind. 7. Wycliffe, Ballard Co., Ky. 8. Flint clay, Louisville, Carter Co., Ky. 9. Flint clay, Mount Savage, Md. 10. Christy Clay Co., St. Louis, Mo. 11. Flint clay, Rolla, Mo. 12. Woodbridge, Middlesex Co., N. J., W. B. Dixon bank. 13. Woodbridge, Middlesex Co., N. J., retort clay. 14. White clay, Kreischer's pit, Kreischerville, Boro' Richmond, N. Y. 15. Eskridge pit, Grover Cleveland Co., N. C. 16. Flint clay, Mineral Point, O. 17. Ballou fire clay, Muskingum Co., O. 18. Five miles southwest Clearfield, Clearfield Co., Pa. 19. South Fork, Cambria Co., Pa. 20. Rapid City, South Dakota, 21. Montague Coal Mining Co., Henderson Co., Tex. 22. Soft clay, Spragueville, Preston Co., Wash.

As can be seen from the above table, there is always a small percentage of fluxes, and in most cases the total quantity rarely exceeds 4 or 5%. Another point to be noted is the variation in the percentages of silica and alumina, some fire clays being highly siliceous, while others are very aluminous. The latter also show a high content of combined water. While it has usually been considered that a small quantity of fluxes added to a very refractory clay will tend to lower its refractoriness, it seems possible under certain conditions to add a large amount of some fluxing material without materially decreasing the refractoriness

of the clay. This is of special bearing in the case of highly siliceous mixtures, as shown by E. Cramer,[1] who was led to experiment by the fact that very highly siliceous rocks, as quartzite schist, when used as a lining in lime and cement kilns, were apparently free from any fluxing action although in contact with the kiln contents at a very high temperature. He experimented with artificial mixtures of carbonate of lime and sand or kaolin, and obtained the following results:—

Fusing Point Seger Cones.	Chemical Composition.		
	CaO.	Al_2O_3.	SiO_2.
Under 26	31·8	.....	68·2
35	.....	46·2	53·8
29–30	23·7	.....	76·3
33	.....	36·4	63·6
32	18·9	.....	81·1
32	.....	30·0	70·0
Much under 26	11·2	41·0	47·8
32–33	10·4	.....	89·6
29	.....	17·6	82·4
30–31	5·9	43·5	50·6

These results show that the introduction of the kaolin lowered the fusing point appreciably.

The manner in which the flux is distributed in the clay must be considered in connection with its effect on refractoriness. If the fluxing material is finely distributed it will be more effective than if the same quantity were in larger grains here and there in the material. This variation in the distribution of the fluxing material is often seen in the case of iron, which, when evenly scattered through it, gives the clay a uniform tint and when present in small lumps shows spots of rust forming fused specks in burning. In the latter case the iron in the raw clay may be present as pyrite, commonly known to the workman as sulphur balls, which are readily recognized by their metallic luster and yellowish color; as limonite concretions often derived from the weathering of pyrite, or as siderite. Many fire clays contain from a few tenths to several per cent. of titanium, but its effect is seldom considered, as its fluxing action is of no moment when present in small quantities. Silica is regarded as a refractory constituent at low temperatures, and as a flux at high temperatures unless in excess.

Although the size of grain is considered by many to influence the fusibility of a clay, others[2] claim that the size of grain has nothing to do with the heat-resisting quality of the clay. The fusibility of several well-known American fire clays expressed in terms of Seger cones are given in the subjoined table, which includes for comparison several foreign clays:—

Locality.	Seger Cone Number.	Locality.	Seger Cone Number.
White fire clay, Kreischerville, N. Y.	35	Altwasser, Prussia	36
Christy fire clay, St. Louis, Mo.	30	Wiesau, Germany	32
Golden, Colorado	31–32	Geoppersdorf, Germany	34
Mineral Point, Ohio	33	Gross-Almerode, Germany	33
Mt. Savage, Md. (hard)	34–35	Vallendar, Rhine Province	33
Sayreville, N. J.	35		

Plasticity and Tensile Strength.—The plasticity of fire clays varies from

[1] *Thonindustrie Zeitung*, 25, 976.

[2] H. O. Hofman, *Transactions of the American Institute of Mining Engineers*, 1898, Vol. XXVIII., p. 440.

nothing in the flint clays to a high degree in many clays from New Jersey. This naturally means a variation in tensile strength, which may range from a few pounds per square inch in lean, sandy clays, to 200 lb. or more in very plastic ones.

Air- and Fire-Shrinkage.—The shrinkage of fire clays is often in close agreement with the degree of plasticity which they possess. As a rule fire-brick mixtures show a very low shrinkage as they contain much non-plastic material, but many of the ingredients are clays of high plasticity and consequently of high shrinkage and bonding power; it is on account of the last-mentioned quality that they are added for the purpose of holding the non-plastic elements together. All fire clays do not shrink in burning, and those of high silica content may expand slightly. In a series of tests by Cramer, pure silica or quartz, heated alone, increased in size from 3·1 up to 9·5%. The melting point was usually quite high and the swelling was found to increase continuously as the heating proceeded. Highly plastic fire clays often burn to a very dense body; the temperature at which this densification takes place, however, is not the same in all cases. Fire clays used in the manufacture of glass pots may become very dense at a temperature slightly above 2,000° F., while others may not show this same condition until they have been heated to at least 2,400 or 2,500° F.

Occurrence.—Fire clays occur under a variety of conditions. They are sometimes associated with beds of coal, or interbedded with sandstones, limestones, or other sedimentary rocks, or again in the form of a thick series of beds, all of which are more or less refractory in their character. It is a common custom among coal miners to apply the term fire clay to almost every underclay found associated with the coal seam, and while this term is a correct one in many regions in Pennsylvania or Indiana, it does not follow that every clay underlying a coal bed is refractory. In Michigan, the coal beds are invariably underlain by a bed of clay or shale, often of gray color and carrying plant remains. These are called fire clays, yet not one of them is refractory, as far as experience goes. Fire clays may often be interbedded with other plastic materials of a much less refractory nature. In some formations, as the Carboniferous, the clay deposits are often continuous over considerable areas while in others, as the Cretaceous beds of the coastal plain region, they frequently assume a lenticular form, thinning out horizontally, although of very great thickness in the central part of the mass. All fire clays are not sedimentary in origin, some being residual from the decomposition of feldspar veins.

The cause of the freedom of certain clay beds from fusible impurities has been explained in several ways. From the fact that many fire-clay beds underlie coal, it has been thought that the roots of the plants growing in the swamp under which the clay lay absorbed the alkalies and other bases from them. Against this may be pointed out that many clay beds of refractory character are not associated with deposits of plant remains. It has also been suggested that the leaching out of the fluxing impurities by surface waters purified the fire clays, but if this were true, the outcrops would be more refractory than the deeper or more buried parts of the bed—a condition not always present, and in some cases the reverse. It seems more probable that the fire-clay particles have come from the decomposition and erosion of rocks which were comparatively free from iron-

bearing minerals, and during the decomposition of the parent rock, many of the fluxing impurities were carried off in soluble form.

Mining of Fire Clays.—Two methods are usually adopted—the open pit or quarry method, and the drifting or underground method. The former is used where the clay outcrops at the surface and has little or no overburden. If the deposit is large and uniform throughout, the material can often be dug rapidly and economically with a steam shovel, but if the bed is small or the section involves a number of beds showing widely different characters, it generally becomes necessary to dig the material with pick and shovel, in order to avoid mixing the different varieties. The steam-shovel method of mining is applicable in some deposits in Ohio, while the open pit method is the one mostly used in other regions. Underground working is necessary where the fire clay is overlain by a considerable thickness of other material of no economic value. In some cases horizontal beds outcrop on the side of a hill or mountain, in which case it is customary to run a drift into the hill and drive radiating gangways from this. In other cases the shale bed has to be reached by means of a shaft from which levels are driven into the fire clay. In regions where this is necessary the refractory clays are often found interbedded with coal or other clays of considerable value. Many clays in Pennsylvania are worked by drift, while in Indiana and Missouri, the shaft method of mining is often adopted.

Geological Distribution.—Refractory clays are found in many formations from the pre-Cambrian to the Tertiary. The pre-Cambrian fire clays are of residual nature and rarely of great extent, being more or less veinlike in form. They occur at several points in the southern Appalachian region. There is no reason why residual fire clays should not be formed from igneous or metamorphic rocks of pre-Cambrian or other ages, but they are not known to exist in any quantity in the United States; in Germany, however, some of the more refractory clays are derived from the weathering of quartz porphyry. The Carboniferous is one of the most important American sources of plastic and the flint fire clays, and deposits are found in Pennsylvania, Ohio, Kentucky, Indiana, and Missouri. The Cretaceous contains vast supplies of fire clay in the Atlantic coastal plain region of the United States, which are especially abundant in New Jersey and are also known in Maryland, North Carolina, Georgia, Alabama, and Texas. The Jura-Trias contains no refractory materials in the Eastern States, but some of the fire clays found along the eastern Rocky Mountains belong undoubtedly to this age. Fire clays of Tertiary period are known in the Atlantic States, and also in the Cordilleran region, but as compared with those of the Cretaceous, they are very little developed. Up to the present time few refractory clays of Quaternary period have been developed in the United States. They are known in New Jersey.

Geographical Distribution of Fire Clays in the United States.—Many State surveys have taken up the investigation of their clay resources, and much information is to be obtained from these reports, but there are other States containing an abundant supply of refractory material which has never been systematically investigated, owing often to the absence of a State survey.

Alabama.[3]—Refractory and semi-refractory clays are found chiefly in the

[3] H. Ries, "The Clays of Alabama," Bulletin No. 6, *Alabama Geological Survey.*

Cretaceous formation, but are also known in the Carboniferous. The latter are found at Fort Payne and Valley Head. Some refractory clays are also seen in association with the bauxite deposits near Rock Run. The fire brick works at Ensley, near Birmingham, have drawn much of their raw material from Woodstock, Bibbville, and Anniston. It is not unlikely that the residual kaolins found in the areas of crystalline schists may be found of value for the manufacture of fire brick at some future time, but at present most of them are located some distance from the railroad.

Arkansas.[4]—Little has been published on the clays of this State, but an abundance of good material is said to occur in the Mesozoic formations.

Colorado.[5]—There are many important fire-clay beds of Cretaceous age occurring in the eastern foothills of the Rocky Mountains. The deposits usually dip at a high angle and are interbedded with sandstones of Dakota age. Some of the clays are of high refractoriness, and can be used in the manufacture of fire brick, crucibles and assayers' apparatus. They have been actively mined near Golden and at several other localities, and form the basis of an important local industry.

Delaware.—Fire clays of Cretaceous period are said to be worked to a small extent. Some of them are used in the manufacture of chemical stoneware.

Georgia.[6]—The Potomac formation contains many clays of a white or nearly white color and of considerable refractoriness. They are mined at several localities along the Fall line, notably around Griswoldsville, but are little used in the manufacture of fire brick.

Indiana.[7]—Many beds of fire clay are found in the Coal Measures, and occur interbedded with coal seams, as well as with other clays or shales of less purity. The beds are often quite persistent, being pierced at many localities by shafts.

Kansas.—So little clay of good quality is found in this State that all of that required by the zinc smelters has to be shipped in from other States.

Kentucky.[8]—Both plastic fire clays and flint clays have been found in the State, and while an abundance of material is reported, the deposits have not been exploited systematically. A number of analyses are given in the reports of the Kentucky Geological Survey, referred to below. The known deposits are of Carboniferous and Cretaceous age, and exist in the counties of Ballard, Bell, Boyd, Calloway, Carter, Edmonson, Graves, Grayson, Fulton, Hickman, and Muhlenberg.

Maryland.[9]—This State contains three classes of fire clay, *viz.:* (1) Flint and shale clays of the Carboniferous period, which are worked at several points along Savage Mountain in Alleghany County and manufactured into the well-known Mount Savage fire brick. These clays occur also in Garrett County. (2) Potomac clays, forming lenticular deposits at many points in the coastal plain, and

[4] *Mineral Resources, United States Geological Survey*, 1891. p. 516.

[5] H. Ries, "The Clays and Clay-working Industry of Colorado," *Transactions of the American Institute of Mining Engineers*, 1897. p. 336; Emmons, Cross & Eldridge, "The Geology of the Denver Basin, Mont.," 27, *United States Geological Survey*, p. 387; S. Geijsbeck, "The Clays of Colorado," *Clay Worker*, 36, 424.

[6] G. E. Ladd, "The Clays of Georgia," Bulletin 6-A, *Georgia Geological Survey*.

[7] W. S. Blatchley, Twentieth Report, *Department of Geological and Natural Research*, p. 40.

[8] *Kentucky Geological Survey*, Chemical Reports, A, Parts I., II. and III.

[9] "The Clays of Maryland," by H. Ries, *Maryland Geological Survey*, Vol. IV.

cases the harder lumps are given a preliminary grinding in a dry pan. After the mixture has been thoroughly worked or tempered it may be carried directly to the molding floors, or, if not required for immediate use, it is stacked up in bins and covered with cloths to prevent the evaporation of moisture as much as possible.

Molding.—Fire brick manufacturers originally molded ordinary shapes of fire brick by the soft-mud process, and, while some of them a few years ago tried the stiff-mud, or the dry-press process, the conclusion has been reached that the soft-mud method of molding is the best. In molding soft-mud fire brick some works form the common shapes by hand-pressure in wooden molds, while others prefer the soft-mud brick machine, operated by steam power. The stiff-mud process is sometimes used and in rare instances the semi-dry process. The product in either case is a very soft green brick of rather rough shape, which has to be re-pressed, usually in a hand-power machine. The re-pressing makes the brick somewhat denser, and straightens the edges and corners.

Drying and Burning.—Drying is usually done on floors heated by flues passing underneath from a coal fire at one end.

Burning was formerly done in up-draft or down-draft kilns, but at the present most manufacturers use a circular down-draft kiln of diameter varying from 15 to 25 ft. In the case of fire brick less skill is required for successful burning than in most other branches of the clay-working industry. Color is not an item that has to be considered, and, on account of the refractory nature of the clay, there is no danger of overburning, for the temperature of fusion of the brick is never attained in the kiln. Some of the brick may come from the kiln softer than others, but this does not mean a loss, as many prefer a soft brick to a hard one. The temperature attained in most fire-brick kilns probably never exceeds 2,400°F. The forming of large or complicated shapes of fire brick, such as slabs, tiles, or other pieces, cannot be done by machinery. These are usually shaped by hand in wooden molds, often filled with more clay than necessary, and set into a machine. On applying pressure on the top of the clay, the excess is squeezed out and scraped off, the mold is then emptied on to the drying floor or to a wooden pallet and subsequently carried to the drying-room.

Fire bricks are not subjected to as much heat in drying as other bricks, and Eastern manufacturers usually dry them at a higher temperature than those in the West.

Gas Retorts.—The manufacture of gas retorts represents a branch of the refractory ware industry which is of decreasing importance. In making these retorts, large sectional wooden molds are used, the retort being built on end. The mold consists of an outer shell and a wooden core, whose surface is the same as the interior surface of the retort. The lower section of the mold is set on the planking on which the retort is to be built up, and the first section of the core placed inside of it, the space between the two being tamped full of clay. Then a second section of the mold is set on the first, and the clay filled in until the entire length of the retort is built up. When completed, the core is withdrawn and the shell of the mold removed. The retort remains standing on end and is carefully dried for several weeks before being placed in the kiln for burning.

Glass Pots.—The manufacture of glass pots represents probably the highest branch of the refractory clay industry, as it requires not only the best grades of clay, but also great skill and care during the entire process of manufacture. Furthermore, the product is one of the very few forms of refractory material which is not burned before use. For many years the glass-pot clays used in the United States were imported, mainly from Germany and Belgium, but at present, although the imports have not entirely ceased, much native clay is used. The requirements of a glass-pot clay are most severe, for in use the pots are not only subjected to high temperature, but also to the corrosive action of powerful fluxes, as soda or lead. The raw material must therefore be refractory, in order to resist the fluxing action of the molten glass; it must be plastic to a marked degree in order to bind the mass together, especially as more or less non-plastic material is put into the mixture and the pot in the green condition has to hold together when moved, and finally it must have a proper density when burned at a low temperature.

The American glass-pot clays are obtained chiefly from Missouri and Pennsylvania, although small quantities are mined in Ohio. Some clays are washed before use and all raw materials are rigidly examined, to insure proper quality.

Homogeneity is of great importance, and the miners of the clay often allow it to weather from several months to two years or more before it is used. The mixture is carefully ground, tempered, and stored under moist blankets until used. The pot is built up piece by piece, using special clays in the top, sides and bottom, depending on the action to which each will be subjected.

From one month to six weeks may be required to complete a pot, and several additional weeks for drying. The pot is then sent to the glass factory, where it is put into the furnace and heated up very slowly. It is not allowed to cool until it is worn out, which may be several months. The tank furnaces used in the manufacture of glass are lined with large tightly-fitting blocks of refractory material similar in composition to that used in making the glass pots.

Review of Literature of Clays and Clay Products for 1901.

By Heinrich Ries.

Clay Deposits.

United States.—*Colorado.*—The Colorado clay deposits are described by S. Geijsbeck in the *Clayworker,* Vol. 36, p. 424, dwelling chiefly on the Mesozoic fire clays occurring along the eastern foothills of the Rocky Mountains.

Iowa.—In the *Eleventh Report of the Iowa Geological Survey* the clays are referred to under the special reports on Louisa, Marion, Pottawattomie, Cedar, Page, Clay and O'Brien counties.

Wisconsin.—The clays and clay industries of Wisconsin are treated by E. R. Buckley, in the *Report of the Wisconsin Geological and Natural History Survey* (Bulletin No. 8, Part I., Economic Series, No. 4). The State contains a variety of clays suitable for the manufacture of brick and tile. The residual clays are derived from both igneous and sedimentary rocks, while the transported clays are of glacial Lacustrine or Æolian origin. The clays of the extreme northern,

eastern and southern parts of the State are very calcareous; those found in the southwestern, western, and northern central portions are moderately so, while in the central section, which borders the area of crystalline rocks, they are very low in calcium. White-burning sedimentary clays occur in the western and central portions of the State, and some are washed and prepared for paper manufacturers.

FOREIGN COUNTRIES.—*Austria.*—F. Ulzer, in the *Mittheilung des k. k. Thon. Gewerbe Museum,* in Wien, 1900, 10, 190-191, describes a washed kaolin which had 2·95% Fe_2O_3 and in burning became yellow at 1,270°C. The locality is not given.

British Guiana.—In the *Engineering and Mining Journal,* August 17, 1901, the existence of a superior grade of kaolin is reported from the district along the Corentine River in British Guiana. The analysis of this kaolin is: H_2O, 8·01%; TiO_2, trace; Fe_2O_3, 1·21%; Al_2O_3, 24·16%; CaO, 0·39%; MgO, 0·27%; potash, 0·04%; soda, 0·01%; sand, 23·35%; SiO_2, 41·98%.

Germany.—Kaolin from Hirscham, Germany, as stated by the *Thonindustrie Zeitung,* Vol. 25, p. 2005, showed SiO_2, 47·84%; Al_2O_3, 38·19%; Fe_2O_3, 0·7%; CaO, 0·65%; MgO, trace; K_2O and Na_2O, 0·66%.

Italy.—Some of the china clay used in Italian industry is obtained from domestic sources, yet the larger quantity comes from England and France, whose products are superior. Many veins of kaolin are reported to exist in Sardinia, according to the *Journal of the Society of Chemical Industry,* December, 1901, p. 1259. The kaolin pits of the Province of Vicenza, Italy, have been worked for a number of years. The deposit lies along the contact of the Triassic limestone and porphyritic tuff, but the percentage of iron in it is sufficient to prevent its use for porcelain. (*Thonindustrie Zeitung,* Vol. 25, p. 1034.)

New South Wales.—According to the *Report of the Department of Mines of New South Wales* for 1900, fire clay is mined to some extent. Several analyses are given for different localities, one of which, from Newbridge, shows 0·08% V. The clays of New South Wales are referred to and many analyses given in the volume on the *Mineral Resources of New South Wales* for 1901.

Ontario.—Analyses of clay from Marl Bank and East Garafraxa, Ontario, are given in the *Report of the Bureau of Mines,* 1901, p. 16. These clays are used for making Portland cement.

CLAY INDUSTRIES.

Pennsylvania.—W. G. Irwin, in an article in the *American Manufacturer,* 1901, p. 886, on fire clays and the fire-clay industry, makes general reference to some of the better known fire clays of Pennsylvania. The same author, in a paper on the silica brick industry, *Ibid.,* p. 950, refers to the manufacture of these products in Pennsylvania. The plant of the Soisson Fire-Brick Co., at Connellsville, is described on p. 762 in the issue of June 20, 1901, and analyses of the raw material are given.

Formosa.—According to the *Engineering and Mining Journal,* Vol. 72, p. 64, the brick-making industry in Formosa is said to be growing, especially as a result of recent encouragement received from the Japanese, who suggested the use of

kilns for burning bricks. There are now 12 large and prominent factories in which Japanese are interested, which have a total monthly production of 2,500,000 bricks. Roofing and floor tiles are among other clay products.

France.—The clays and clay products at the Paris Exposition of 1900 are described by H. Ries in the *Twenty-first Annual Report of the United States Geological Survey,* Part VI., continued.

Germany.—G. C. Vater describes, in the *Clayworker,* July, 1901, p. 20, the clay mines and works at Gross Almerode, Germany. The clays are used to a large extent in the manufacture of glass pots and shipped to many foreign countries. A large amount of the clay which is of Tertiary age is mined underground.

Philippines.—G. B. Rice, in the *Clayworker,* p. 385, describes the manufacture of fire bricks in the Philippines. The refractory clay occurs from 25 to 50 ft. below the surface. The molding is done in molds of hard wood and the bricks are baked in rather crude kilns.

Russia.—The ceramic industry of Russia is briefly referred to in the *Thonindustrie Zeitung,* Vol. 25, p. 1875.

Scandinavia.—The brick industry of Scandinavia is briefly discussed in an anonymous article in the *Thonindustrie Zeitung,* Vol. 25, p. 1302; also another article which also includes Denmark, in the same volume, p. 1350.

South Africa.—Brick-making in South Africa is referred to in the *Clayworker,* Vol. 36, p. 219.

United Kingdom.—Hecht and Gary, in the *Thonindustrie Zeitung,* Nos. 72 and 73, describe the clay products at the International Building Exposition, held in London.

Refractory Materials.

E. Cramer, in the *Thonindustrie Zeitung,* 1901, Vol. 25, p. 864, gives the results of his examinations of a number of substances used in the manufacture of Dinas bricks and the effect on them of repeated heating. He found great differences in their behavior, especially as regards their density, bulk, and expansion. After eight heatings at cone 16 to 17 the sp. gr. of quartz varied from 2·45 to 2·66. On the first heating there was a very irregular increase in bulk in the different heatings; one specimen of a fusion point the same as cone 36 increased 3·1%, and another of a fusion point cone 35 increased 9·5%. The purest materials seemed to swell only a little at first, later the gain was continuous. The same author, in experimenting on the softening point of refractory clays, as given in the *Thonindustrie Zeitung,* Vol. 25, p. 706, made cylinders of these materials and heated them several times to cone 17, the bars being supported only at the ends. He came to the conclusion that clays became more refractory the oftener they are fired.

Dr. Steger, in the *Thonindustrie Zeitung,* Vol. 25, pp. 1918, 1934, 1956, discusses the different kinds of refractory materials, including magnesia bricks, chromite bricks, lime bricks, carborundum, and refractory tiles. Numerous analyses are given of the raw material obtained from different localities.

The fusing points of a number of quartzites from southern Russia are given

in the *Thonindustrie Zeitung,* Vol. 25, p. 1850. Most of them melt around cone 34, and they increase in size during the heating from 1·2 to 6%.

Silica brick is manufactured to a large extent in western Pennsylvania, much of it being made from sandstone of Medina age (*Clayworker,* Vol. 36, p. 130). The material is abundant in Huntingdon and Blair counties, while ganister deposits are also known.

During the past year an extensive find of flint fire clay has been made at Cowansville, Armstrong County, Pa. It lies in the upper Freeport stratum of the lower Coal Measures.

The manufacture of fire brick is discussed in the *Clayworker,* Vol. 36, p. 314.

Properties of Clay.

Tensile Strength.—I. A. Williams, in the *Clayworker,* Vol. 19, p. 11, discusses the tensile strength of dried clay as a measure of plasticity, and from the results of his tests on a series of Iowa clays, comes to the conclusion that unqualified reliance cannot be placed on the tensile strength of the dry clay as a measure of its plasticity, but that such tests serve as a means of comparison among clays of the same class.

According to E. Orton, Jr., in the *Transactions of the American Ceramic Society,* Vol. 3, p. 204, the tensile strength of mixtures of plastic ball clay with equal quantities of non-plastic sands will vary inversely with the diameter of the grain of sand, from grains of 0·04-in. diameter down to the finest grains obtainable, and furthermore the non-plastic ingredients of the clay influence the tensile strength inversely as the diameter of their grain, the finer-grained clays, other things being equal, possessing the greatest tensile strength.

Composition.—The analyses of several Southern clays lead W. H. Zimmer to believe that some kaolins contain hydrated silicic acid, the action of which is very noticeable on the pottery body. As stated in the *Transactions of the American Ceramic Society,* Vol. 3, p. 25, he finds that the presence of any important quantity of free hydrated silicic acid shows the following tendencies: (1) To produce, at equal temperatures, an increase in translucency over that obtained with quartzitic silica only; (2) to produce a better color; (3) to increase air-shrinkage and fire-shrinkage; (4) to lower temperature of vitrification; (5) to warp in drying; (6) to yield a hard coating which often forms on the surface from the deposition of H_2SiO_3 from water used in making the ware plastic.

Dr. Carl Bischof, in a pamphlet entitled *Gesammelte Analysen der in der Thonindustrie benutzten Mineralien,* has collected in convenient form nearly all of the published analyses of foreign clays as well as many of American origin; analyses of refractory materials, other than clay, are also included.

Bricks.—A. Marston, in a paper in the *Iowa Engineer,* gives the results of a series of experiments on dry-pressed brick as compared with those from surrounding States. The tests included cross-breaking, crushing, absorption, specific gravity, and freezing. The author considers that the cross-breaking tests are of special value. In the absorption tests the brick showed a con-

siderable increase in weight in the first three or four hours, but after the first 24 hours the increase was extremely slight.

FIREPROOFING.—Mäckler, in the *Thonindustrie Zeitung,* Vol. 25, p. 2068, describes the form of fireproofing blocks known as Hourdis, so much used in southern Germany and Italy. They stand in strong contrast to American ones, having a thickness of only 10 mm. with a length of 100 cm. Attempts were made to manufacture these from calcareous clays of northern Germany without success. The analysis of the clay used was: ignition loss, 1·02%; SiO_2, 55·48%; Al_2O_3, 15·16%; CaO, 11·68%; MgO, 5·22%; alkali, 3·70%.

CLAY BALLAST.—W. Shea, in a paper before the Railway Road-Masters' Convention, in Washington, reported in the *Clayworker,* Vol. 19, p. 177, gives the cost per yard of ballast on the cars as follows: Land interest on track material, track labor, and stripping, 4c.; coal, 13·5c.; burning, 17·5c.; hand-loading, 7c.; total, 42c. He considers clay ballast very efficient but not as strong as screened rock ballast, although cheaper to maintain and easier on the rolling stock. The life of the two materials is considered to be about the same, but the life of the railroad tie is about 10% longer on clay ballast. The Chicago and Great Western Railroad is installing a large plant at Des Moines, Ia., for the burning of clay and shale to be used as ballast.

PAVING-BRICK.—The committee appointed by the National Brick-Makers' Association for determining the best methods of testing paving brick has handed in its final report, and according to the *Clayworker,* Vol. 36, p. 436, has adopted the following specifications for a standard method of conducting the rattler test:—

I. Dimensions of the Machine.—The standard machine shall be 28 in. in diameter and 20 in. in length, measured inside the rattling chamber. Other machines may be used, varying the diameter between 26 and 30 in., and in length from 18 to 24 in., but if this is done, record of it must be attached to the official report. Long rattlers must be cut up into sections of suitable length by the insertion of an iron diaphragm at the proper point.

II. Construction of the Machine.—The barrel may be driven by trunnions at one or both ends, or by rollers underneath, but in no case shall a shaft pass through the rattler chamber. The cross-section of the barrel shall be a regular polygon, having 14 sides. The heads shall be composed of gray cast iron, not chilled nor case-hardened. The staves shall preferably be composed of steel plates, as cast iron wears and ultimately breaks under the wearing action on the inside. There shall be a space of 0·25 m. between the staves for the escape of dust and small waste pieces.

Other machines may be used having from 12 to 16 staves, with openings from 0·125 to 0·375 in. between staves, but if this is done a record of it must be attached to the official report of the test.

III. Composition of the Charge.—All tests must be executed on charges containing but one make of paving material at a time. The charge shall be composed of the bricks to be tested and iron abrasive material. The brick charge shall consist of that number of whole bricks or blocks whose combined volume most nearly amounts to 1,000 cu. in., or 8% of the cubic content of the rattling

chamber. (9, 10, or 11 bricks are required for the ordinary sizes on the market.) The abrasive charge shall consist of 300 lb. of shot made of ordinary machinery cast iron, of two sizes, as described below, and the shot charge shall be composed of 75 lb. of the larger size and 225 lb. of the smaller size.

IV. Size of the Shot.—The larger size shall weigh about 7·5 lb. and be about 2·5 in. square and 4·5 in. long, with slightly rounded edges. The smaller size shall be 1·5-in. cubes, weighing about 0·875 lb. each, with square corners and edges. The individual shot shall be replaced by new ones when they have lost 10% of their original weight.

V. Revolutions of the Charge.—The number of revolutions of the standard test shall be 1,800 and the speed of the rotation shall not fall below 28 nor exceed 30 per minute. The belt power shall be sufficient to rotate the rattler at the same speed whether charged or empty.

VI. Condition of the Charge.—The bricks composing a charge shall be thoroughly dried before making the test.

VII. Calculating the Results.—The loss shall be calculated in percentages of the weight of the dry brick composing the charge; and no result shall be considered as official unless it is the average of two distinct and complete tests, made on separate charges of brick.

POTTERY.

History.—In an article in the *Thonindustrie Zeitung,* Vol. 25, p. 1368, the manufacture of Delft ware is said to have been commenced at Delft by Hermann Peters, in the beginning of the seventeenth century. By 1620 eight factories were in operation, and in 1670, 28 were running.

C. F. Binns, in the *Transactions of the American Ceramic Society,* Vol. 3, discusses the birth of English porcelain, and states that it really had its beginning in 1744. The composition of different materials used in its manufacture is also given.

R. L. Cawood, in the *Clayworker,* Vol. 37, p. 60, gives an interesting account of the evolution of the pottery industry of the United States, and points out the wonderful strides which the industry has made during the past 25 years.

The history of the Aachen pottery works is given in the *Thonindustrie Zeitung,* Vol. 25, pp. 77-78.

Pottery Mixtures.—E. Lindner, in the *Sprechsaal,* 1901, pp. 34-36, discusses porcelain sands and the composition of porcelain pastes. The composition of a porcelain body must be such that it will not only withstand temperature changes but also be plastic and transparent, the latter property varying with the temperature of the firing. Silica varies from 58 to 72%; Al_2O_3, 22 to 35%, and K_2O not above 5%. The calcining of flint before putting it into the body decreases breakage in firing. He also states that the most perfect porcelains are those in which the silica is completely combined with the alkali. Lime tends to increase the warping, but is sometimes used as a flux. Sandy pastes if not burned to vitrification may show great indifference to changes in temperature.

S. G. Burt, in a paper on the "Fineness of Flint and its Relation to the Manufacture of Pottery Bodies," in the *Transactions of the American Ceramic*

Society, Vol. 3, p. 17, discusses whether there is any difference in the effect produced by the use of French flint, silica sand, or rock flint, in pottery bodies and concludes that the difference, if any, is extremely slight, and that with uniform fineness of grain equally good results can be obtained by the use of any of those three kinds of flint, but that the variation in the degree of fineness may cause considerable variation in the behavior of the glaze.

Glazes.—In a report made to the Home Secretary on the "Use of Lead in the Manufacture of Pottery," by J. E. Thorpe, noted in the abstracts of the *Journal of the Society of Chemical Industry,* May, 1901, p. 475, the author comes to the conclusions that the lead in glazes is insoluble in a 0·25% HCl solution provided the ratio of bases to acids does not exceed 1·45 : 1·00. Finer grinding increases the solubility of the lead, still it was not as much as was expected. Most glazes when ground sufficiently fine for commercial purposes were found to be within the limits of insolubility prescribed for. It was also found that the insolubility of the lead does not depend on the actual quantity of this metal in the glaze.

In discussing the permissible variation in the silica and alumina content of raw lead glazes, W. M. Fickes, in the *Transactions of the American Ceramic Society,* Vol. 3, p. 112, finds that good, perfect glazes can be produced with other oxygen ratios than 1 : 2, but that ratios between 1 : 1·5 and 1 : 2 are the safest limits for raw lead glazes. The molecular ratio seems to exercise an important function in controlling the hardness of the glazes and the tendency to crystallization during cooling; between the molecular ratios of 1 : 8 and 1 : 15 there is more chance to form a good perfect glaze regardless of the oxygen ratios and RO elements than with other numbers, for each combination in which good glazes can be produced will depend on the fluxing power.

Under the heading of "New Glaze Fluxes," W. Cannon (*Ibid.*' Vol. 3, p. 113) states that dolomite can be successfully used in place of whiting in many glazes, the results being the production of a better color and lack of crazing than any corresponding white glazes. He points out the abundance of dolomitic limestone, especially in Ohio, and believes that it can be used to replace the English whiting, which is much more expensive.

The ceramic stoneware made by the Sever's Porcelain works for the Paris Exposition is described by G. Vogt, in *La Ceramique,* 3 (133), 127-131; (abstracted in the *Journal of the Chemical Society of Indiana,* June, 1901, p. 500). Mr. Vogt describes the manufacture of this material and gives the composition of the glazes and the proportions of the different clays used.

Improvements in the bodies of stoneware and the increasing use of this material for chemical work is pointed out by C. Schatler, in the *Zeitschrift für Angewandte Chemie,* 1901, pp. 728-733.

H. Haskovec gives the following analysis of sand used for the manufacture of silica balls: SiO_2, 98·54%; Al_2O_3, 0·15%; Fe_2O_3, 0·32%; MgO, 0·03%; CaO, 0·01%; alkali, trace; ignition loss, 0·22%. This silica is considered to represent the composition he adopted for use in glazes.

J. Salt, in a paper on the "Flow of Underglaze Colors in Pottery," in the *Moniteur Ceramique,* Vol. 32, p. 138, points out that the "flowing of these printed

colors (chiefly blue, black, and dark green) of the underglaze when fired is produced by the aid of copper oxide added to the colors themselves or in some case by putting a mixture of lime and common salt in saggers with the printed ware. Similar results may be obtained by the presence of tin compounds and salt in the coloring glaze."

PYROMETERS.—A. F. Hottinger, after experimenting with Seger cones, concluded that "in the Cramer cones, which use a boro-silicate fritt, the oxide of iron should be dropped out because it introduces an element of uncertainty, but that this substance is not in itself the cause of irregular behavior of the Cramer cones when used in muffle terra cotta kilns," the real causes being due to the expulsion of boric acid from the cones by sulphuric acid generated in the fuel and also in the conversion of calcium carbonate into calcium sulphate in the same manner. As a result of these two changes the ratio of fluxing ingredients is greatly interfered with, so that a cone no longer melts at the proper temperature, or even melts in a normal manner when it finally does go over. He therefore recommends the use of another fritt which will not be so readily acted upon by acid vapors. He further says that little or no free lime should be used in the construction of the Cramer cone series.

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COAL AND COKE.

THE great industrial prosperity of the United States during 1901, resulted in an increased demand for, and supply of, coal during the year, the production reaching the enormous figure of 293,298,516 short tons (266,078,668 metric tons), as compared with 268,315,433 short tons (243,414,163 metric tons) during 1900. The consumption of coal in the United States during 1901 was 260,509,235 metric tons, against 237,289,307 metric tons in 1900. The total production of the chief countries in the world during 1900 was 765,158,161 metric tons, against 724,772,937 metric tons in 1899.

TOTAL PRODUCTION OF COAL IN THE UNITED STATES. (IN TONS OF 2,000 LB.)

States.	1900.			1901.		
	Tons.	Value at Mine.		Tons.	Value at Mine.	
		Total.	Per Ton.		Total.	Per Ton
Bituminous:						
Alabama	8,504,327	$10,205,192	$1·20	9,099,052	$10,000,892	$1·64
Alaska (*b*)	2,600	14,950	5·75	(*f*)	(*f*)	(*f*)
Arkansas	*a* 1,250,000	1,687,500	1·35	1,816,136	2,068,613	1·14
California	177,515	485,126	2·73	151,079	394,106	2·61
Colorado (*e*)	5,436,490	10,872,980	2·00	5,635,435	6,248,151	1·11
Georgia	248,000	260,050	1·04	354,825	426,685	1·20
Illinois	*a*25,153,929	22,510,360	0·89	27,331,552	28,163,937	1·03
Indiana	6,357,976	6,675,875	1·05	6,918,225	7,016,143	1·01
Indian Territory	*a*1,900,127	3,534,236	1·86	2,421,781	3,915,268	1·62
Iowa	5,089,651	6,968,866	1·37	5,617,499	7,822,605	1·39
Kansas	4,507,201	5,634,001	1·25	4,900,528	5,991,599	1·22
Kentucky	4,901,204	3,908,113	0·78	5,469,986	5,213,076	0·95
Maryland	3,923,808	4,198,475	1·07	5,113,127	5,046,491	0·99
Michigan	843,476	1,307,388	1·55	1,241,241	1,753,064	1·24
Missouri	*a*2,905,022	3,643,975	1·21	3,802,088	4,707,164	1·24
Montana	1,705,957	2,968,395	1·74	1,396,081	2,009,316	1·44
Nebraska (*d*)	900	2,500	2·78	(*f*)	(*f*)	(*f*)
New Mexico (*d*)	*a*1,145,739	1,722,780	1·50	1,084,257	1,540,357	1·42
North Carolina	17,744	22,180	1·25	(*g*)	(*g*)	(*g*)
North Dakota (*b*)	162,929	171,075	1·05	166,601	214,151	1·29
Ohio	20,671,254	20,257,829	0·98	20,943,807	20,928,158	1·00
Oregon	51,050	135,640	2·66	69,011	173,646	2·52
Pennsylvania	79,318,362	77,731,995	0·98	82,305,946	81,397,586	0·99
Tennessee	3,904,048	4,294,928	1·10	3,633,290	4,697,380	1·32
Texas (*c*)	1,022,827	1,871,773	1·83	1,107,953	1,907,024	1·72
Utah	1,233,978	2,443,276	1·98	1,322,614	1,666,092	1·26
Virginia	2,504,974	2,179,327	0·87	2,725,873	2,353,989	0·96
Washington (*d*)	2,418,034	4,425,002	1·83	2,578,217	4,271,076	1·66
West Virginia	*a*21,153,340	14,165,183	0·67	24,068,402	20,848,184	0·87
Wyoming	4,129,265	5,161,581	1·25	4,485,374	6,060,462	1·33
Total bituminous Sh. tons	210,821,727	$219,460,521	$1·04	235,759,980	$236,305,214	$1·05
Total bituminous Met. tons	191,256,216	.....	1·15	204,808,110	.....	1·15
Cannel:						
Kentucky Sh. tons	29,471	$88,413	$3·00	(*h*)	.....	.....
Kentucky Met. tons	26,736	.....	3·31	(*h*)	.....	.....
Anthracite:						
Colorado	59,244	$177,732	$3·00	64,580	$193,740	$3·00
New Mexico	*a*41,595	114,385	2·75	2,260	6,205	2·75
Pennsylvania	57,363,396	102,680,479	1·79	67,471,667	112,504,020	1·67
Total anthracite. Sh. tons	57,464,235	$102,972,526	$1·79	67,538,536	$112,704,055	$1·67
Total anthracite. Met. tons	52,131,213	.....	1·97	61,270,558	.....	1·84
Grand total coal. Sh. tons	268,315,433	$322,521,530	$1·20	293,298,516	$349,009,269	$1·19
Grand total coal. Met. tons	243,414,163	.....	1·32	266,078,668	.....	1·31

(*a*) **Fiscal year.** (*b*) All lignite. (*c*) One-third lignite. (*d*) One-half lignite. (*e*) One-seventh lignite. (*f*) Included in California. (*g*) Included in Georgia. (*h*) Included in bituminous.

TOTAL PRODUCTION OF COKE IN THE UNITED STATES. (IN TONS OF 2,000 LB.)

States.	1900. Tons.	1900. Value at Oven. Total.	1900. Value at Oven. Per Ton.	1901. Tons.	1901. Value at Oven. Total.	1901. Value at Oven. Per Ton.
Alabama	1,992,561	$6,376,195	$3·20	2,148,911	$6,062,616	$2·82
Colorado	575,447	1,726,341	3·00	671,308	1,626,279	2·42
Georgia	72,000	212,640	2·95	54,550	154,025	2·83
Illinois	1,800	4,320	2·38	(e)	(e)	(e)
Indiana	1,249	3,123	2·50	(e)	(e	(e)
Indian Territory	a 47,800	184,030	3·85	37,374	154,884	4·14
Kansas	275,000	618,750	2·25	7,138	15,079	2·11
Kentucky	72,975	158,389	2·17	100,285	208,015	2·07
Missouri	2,368	6,022	2·54	4,749	9,968	2·10
Montana	54,697	318,789	5·83	57,004	337,331	5·92
New Mexico	a 42,808	139,966	3·27	41,643	118,368	2·84
Ohio	48,648	132,809	2·73	108,774	299,430	2·75
Pennsylvania (c)	12,189,912	32,912,762	2·70	14,355,917	27,006,361	1·89
Tennessee	494,438	1,186,655	2·40	404,017	952,782	2·36
Utah	35,018	168,763	4·82	(d)	(d)	(d)
Virginia	651,578	1,348,766	2·07	907,130	1,483,670	1·64
Washington	35,921	176,013	4·90	49,197	239,028	4·86
West Virginia (b)	a 2,598,283	4,546,995	1·75	2,283,700	4,110,011	1·80
Wyoming	14,501	50,573	3·50	564,191	1,607,476	2·85
Total coke { Short tons	19,206,994	$50,272,050	$2·62	21,795,883	$44,445,923	$2·04
Total coke { Metric tons	17,424,471		2·89	19,773,095		2·25

(a) Fiscal year. (b) Includes 40,537 tons made in Wisconsin in 1899, and 37,436 tons made in 1900; also, 53,973 tons made in Virginia in 1899, and 64,740 tons in 1900. (c) Includes 4,800 tons made in Wisconsin in 1900. (d) Included in Colorado. (e) Illinois, Indiana, Massachusetts, Michigan, New York and Wisconsin in 1901, included in Wyoming.

UNITED STATES PRODUCTION OF COAL, 1897-1901. (IN TONS OF 2,000 LB.)

Year.	Alabama.	Arkansas	California.	Colorado.	Georgia.	Illinois.	Indiana.	Indian Territory	Iowa.	Kansas.
1897	5,893,771	850,000	87,449	3,565,660	196,268	a20,072,758	4,439,489	a1,343,376	4,523,494	3,672,195
1898	6,466,741	a1,134,064	135,795	4,174,037	240,000	a18,599,299	5,435,896	a1,458,098	4,117,359	3,860,405
1899	7,484,763	a918,743	167,161	4,806,879	203,775	a23,434,445	6,158,224	a1,404;442	4,675,000	4,096,895
1900	8,504,327	a1,250,000	177,515	5,495,784	248,000	a25,153,929	6,357,976	a1,900,127	5,089,651	4,507,201
1901	9,099,052	1,816,136	151,079	5,700,015	c354,825	27,381,552	6,918,225	2,421,781	5,619,499	4,900,528

Year.	Kentucky	Maryland	Michigan	Missouri.	Montana.	Nebraska.	New Mexico.	North Carolina.	North Dakota.	Ohio.
1897	3,304,053	4,411,924	152,850	a2,429,388	a1,607,637	500	a729,653	20,611	120,000	12,465,538
1898	3,542,132	4,621,618	378,541	a2,838,152	1,450,971	500	a863,583	6,144	124,526	14,053,829
1899	4,705,439	5,080,248	500,000	a3,191,811	1,409,882	1,000	a1,049,034	26,994	120,597	16,695,949
1900	5,020,675	3,923,808	843,476	a2 995,022	1,705,957	900	a1,187,331	17,744	162,929	20,671,254
1901	5,469,986	5,113,127	1,241,241	3,802,088	1,396,081	.....	1,086,546	(c)	166,601	20,943,807

Year	Oregon	Pennsylvania. Bituminous.	Pennsylvania. Anthracite.	Tennessee.	Texas.	Utah.	Virginia	Washington.	West Virginia.	Wyoming	Totals. (b)
1897	100,929	54,674,272	52,581,036	2,888,849	615,540	506,455	1,418,746	1,489,815	13,950,000	2,744,960	200,857,211
1898	165,871	64,247,859	52,799,774	3,084,748	751,191	571,417	1,640,000	1,988,288	16,499,840	3,181,905	218,333,833
1899	86,886	73,066,943	60,518,331	3,736,134	940,622	882,496	2,111,891	1,917,607	a18,201,189	4,525,207	252,115,397
1900	51,050	79,318,362	57,363,396	3,904,048	1,022,827	1,233,978	2,504,974	2,418,084	a21,153,340	4,129,365	268,315,433
1901	69,011	82,305,946	67,471,667	3,633,290	1,107,953	1,322,614	2,725,873	2,578,217	24,068,402	4,485,374	293,298,516

(a) Fiscal year. (b) Includes from Alaska, 1,300 in 1898, 2,900 in 1899, and 2,600 in 1900. (c) North Carolina included in Georgia.

IMPORTS OF COAL AND COKE INTO THE UNITED STATES. (IN LONG TONS.)

Year.	Coal. Anthracite. Long Tons.	Coal. Bituminous Long Tons.	Coal. Totals. Long Tons.	Coal. Totals. Metric Tons	Coal. Totals. Value.	Coke. Long Tons.	Coke. Metric Tons	Coke. Value.
1897	3,261	1,276,963	1,280,244	1,300,728	$3,432,154	35,193	35,756	$98,558
1898	3,149	1,270,557	1,273,706	1,294,085	3,578,181	41,185	41,844	142,334
1899	61	1,400,461	1,400,522	1,422,930	3,882,675	27,855	28,301	142,504
1900	118	1,909,258	1,909,376	1,939,926	5,020,102	103,175	104,826	371,341
1901	286	1,919,962	1,920,248	1,950,972	5,293,278	72,729	73,883	266,078

EXPORTS OF COAL AND COKE OF DOMESTIC PRODUCTION. (IN LONG TONS.)

Year.	Anthracite.		Bituminous.		Totals.		Coke.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
1897.....	1,296,768	$5,836,730	2,399,263	$5,296,761	3,696,031	$11,163,491	173,084	$546,066
1898.....	1,350,948	5,712,985	3,152,457	6,699,248	4,503,405	12,412,233	199,562	600,981
1899.....	1,707,796	7,140,100	4,044,354	8,573,276	5,752,150	15,713,376	280,196	858,856
1900.....	1,654,610	7,092,489	6,262,909	14,431,590	7,917,519	21,524,079	376,999	1,358,968
1901.....	1,998,807	8,987,147	5,390,086	13,085,763	7,383,393	22,022,910	384,330	1,516,898

PRODUCTION AND CONSUMPTION OF COAL IN THE UNITED STATES. (IN LONG TONS.)

Year.	Production.	Imports.	Total Supply.	Exports.		Consumption.	
				Domestic.	Foreign.	Tons.	Metric Tons.
1897.....	179,886,796	1,280,244	180,617,040	3,696,031	5,297	176,913,712	179,744,331
1898.....	194,940,967	1,273,706	196,214,673	4,503,405	2,890	191,708,378	194,775,712
1899.....	225,108,024	1,400,522	226,508,546	5,752,150	6,806	220,744,590	224,276,503
1900.....	239,567,351	1,909,376	241,476,727	7,917,519	6,740	233,552,468	237,289,307
1901.....	261,873,675	1,920,348	263,793,923	7,383,393	3,808	256,406,727	260,509,235

Ohio.—The production of coal increased very slightly during 1901, the figures being 20,943,807 for that year, against 20,671,254 for 1900.

Pennsylvania.—The production in 1901 amounted to 82,305,946 short tons of bituminous coal and 67,471,667 short tons of anthracite coal, as compared with 79,318,362 short tons of bituminous and 57,363,396 short tons of anthracite coal for 1900. The output of anthracite in 1900 being much restricted by the strike of that year.

West Virginia.—The production of coal for 1901 was 24,068,402 short tons, against 21,153,340 short tons for 1900. Very little of the coal mined in West Virginia is consumed within its borders. The use of mining machines is increasing rapidly in the mines of the State.

Other States.—All of the coal mining States, excepting California, New Mexico and Tennessee, made increases in the output of coal during 1901. The three States enumerated above made very slight decreases, which may be noted by reference to the table at the beginning of this subject.

Exports and Imports.—There was a slight decrease in the exports of coal during 1901, the figures being 7,383,393 tons for 1901, against 7,917,519 tons in 1900. The imports increased slightly from 1,909,258 tons in 1900, to 1,919,962 tons in 1901. Both imports and exports are given in the subjoined table:—

UNITED STATES EXPORTS AND IMPORTS OF COAL CLASSIFIED AS TO COUNTRIES.

Country.	Exports.		Imports.	
	1900.	1901.	1900.	1901.
Australasia.....	*Nil.*	*Nil.*	254,183	351,105
Canada.....	5,422,493	5,080,963	1,484,576	1,438,531
Central and South America.....	223,795	291,816	.....	.....
Europe.....	635,287	589,576	118,987	77,389
Hawaii and Philippine Islands.....	96,870	71,718	*Nil.*	*Nil.*
Japan.....	*Nil.*	*Nil.*	9,045	11,068
Mexico.....	664,036	551,448	41,396	19,702
West Indies.....	760,879	785,389	*Nil.*	*Nil.*
Others.....	114,209	62,483	1,141	22,217
Totals.....	7,917,519	7,383,393	1,909,258	1,919,962

The diagrammatic chart given on page 129 illustrates clearly the relative positions of the different coal producing countries and shows that the United States continues to be the greatest coal producing country in the world—a position it bids fair to occupy for many years to come.

Production of Coal in the Chief Countries of the World.

The total production of coal in the world during 1900 was 765,158,161 metric tons, against 724,772,937 metric tons in 1899, an increase of 40,385,224 metric tons during the year. Detailed statistics may be found in the subjoined table:—

COAL PRODUCTION OF THE CHIEF COUNTRIES OF THE WORLD. (IN METRIC TONS.)

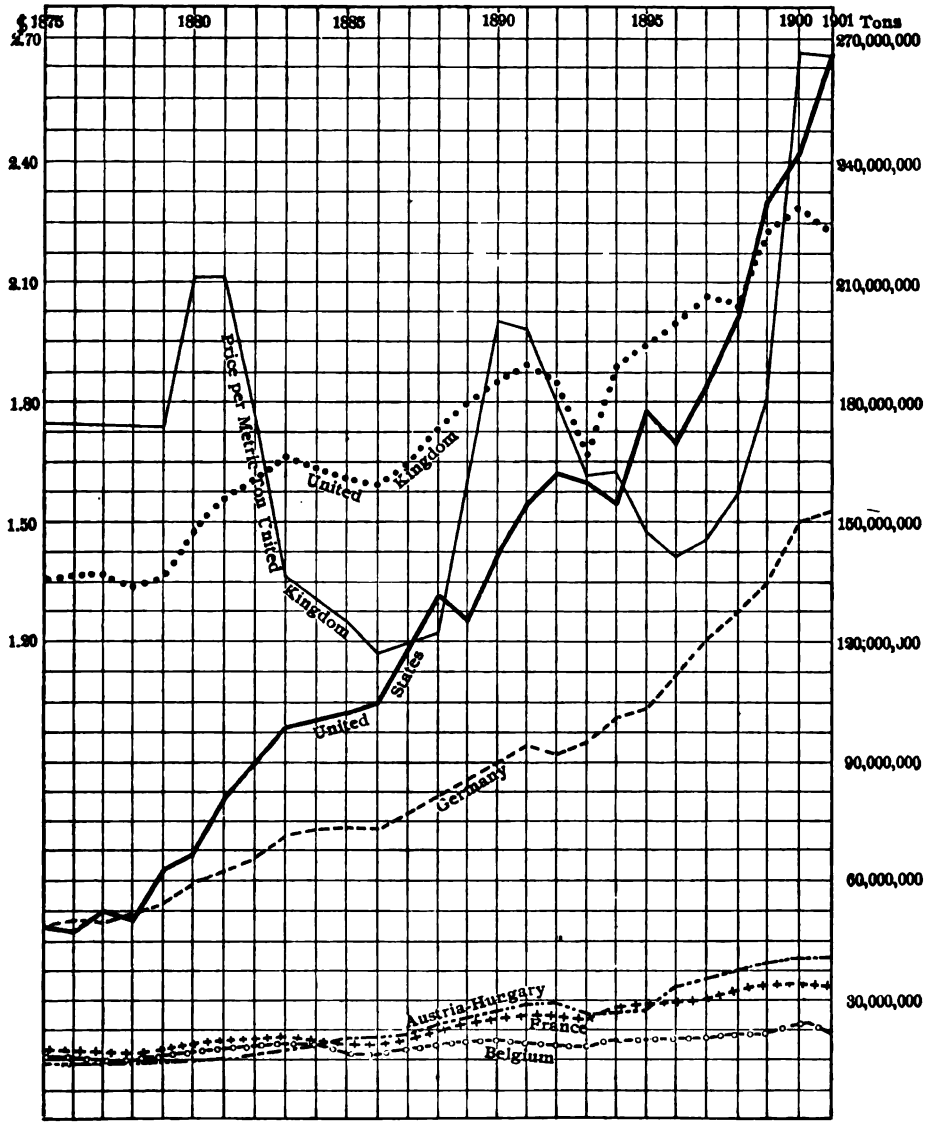
Year.	Africa.	Australasia.					Austria-Hungary	Belgium.	Canada.		France.	Germany.
		New South Wales.	New Zealand.	Queensland.	Tasmania	Victoria.			British Colu'bia & Territories.	N. Brunsw'k, Nova Scotia.		
1896	1,787,908	3,972,068	805,587	977,322	44,286	230,187	33,676,411	21,252,370	1,115,519	2,282,572	29,190,000	111,471,106
1897	2,008,174	4,453,728	854,164	864,142	43,210	240,063	35,939,416	21,492,446	1,167,153	2,267,581	30,798,000	120,474,485
1898	a2,550,485	4,781,551	921,546	414,461	49,902	246,845	37,786,962	22,088,335	1,454,452	2,330,890	32,356,107	127,958,550
1899	a 299,443	4,670,590	990,838	501,913	43,803	266,578	38,738,372	22,072,068	1,601,833	2,866,144	32,862,712	135,844,419
1900	a 495,889	5,595,879	1,111,860	505,252	51,549	215,052	39,027,929	23,462,817	1,791,799	3,296,322	33,404,298	149,551,058

Year.	India.	Italy.	Japan.	Russia. (f)	Spain. (g)	Sweden	United Kingdom.	United States.	All Other Countries	Totals.
1896..	3,909,582	276,197	5,100,005	9,377,551	1,852,947	225,848	198,487,040	170,242,657	e2,000,000	597,677,013
1897..	4,128,137	314,222	5,647,751	11,203,738	2,019,000	224,343	205,364,010	182,216,466	e2,000,000	633,215,229
1898..	4,678,640	341,327	6,651,208	12,307,450	2,466,800	236,277	205,287,388	198,071,199	e2,500,000	665,480,375
1899..	5,016,055	388,534	6,721,798	14,274,361	2,600,279	239,344	223,616,279	228,717,579	e2,500,000	724,772,937
1900..	6,216,822	479,896	7,429,457	15,000,000	2,582,962	252,320	228,772,886	243,414,164	e2,500,000	765,158,161

(a) Includes estimate of 50,000 tons as the output of the Orange Free State and Transvaal, for which no statistics are available. (e) Estimated. (f) 1900 production estimated. (g) Not including lignite.

Canada.—The production of coal in Canada during 1901 was 6,186,286 long tons, valued at $14,671,122, against 5,608,666 long tons, valued at $13,290,429 for 1900, an increase of 577,620 long tons and $1,380,693 in value for the year. The production of coke showed more considerable progress, being 373,625 long tons, valued at $1,264,360 for 1901, against 157,134 long tons, valued at $649,140 for 1900, an increase of 216,491 long tons and $615,220 in value. The exports of coal during 1901 were valued at $5,307,060, against $4,599,602 during 1900, while coke exports for 1901 were $192,910, against $33,770 for 1900, a very considerable increase for the year. The imports of all kinds of coal during 1901 were 414,432 long tons, valued at $275,559, against 330,174 long tons, valued at $98,349 for the previous year. The imports of coke during 1901 were 308,786 long tons, valued at $680,138. The total consumption of coal in Canada during 1901 was 9,718,272 long tons, against 7,932,267 long tons consumed in 1900. The coal fields about Cape Breton, Nova Scotia, continued to furnish the bulk of the production of coal, although British Columbia, New Brunswick, Manitoba and the other territories materially increased their outputs. The anthracite coal measures which range from 3 to 6 ft. in thickness on Queen Charlotte's Island, appear to be of very good quality, and compare favorably with Pennsylvania anthracite. The coal areas of Canada are estimated at 97,200 square miles, excluding areas known but undeveloped.

The Crow's Nest Pass Coal Co., of British Columbia, is rapidly building up a very large export trade with Montana and the Great Northern Railway and others. The annual production of 1901 and the three previous years was as follows: 1901, 425,350 long tons; 1900, 242,245 long tons; 1899, 116,200 long



THE WORLD'S PRODUCTION OF COAL IN METRIC TONS

tons; 1898, 8,996 long tons. It is said that the larger part of the coal supply of southeastern Alaska, the majority of the California coast cities, and the Southern Pacific Railway is derived from the collieries of Vancouver Island, B. C.

China.—A new coal field near Ngankin, on the Yangtse river, Province of Anhui, China, is expected to be in full operation during 1902. The mines are

within a few hours' steamer travel of Shanghai. The coal field is said to be of great extent, and to furnish coal of a very high quality.

Europe.—Coal is said to have been discovered recently in the mountains of Bohemia which is equal in quality and in facility of operation to any in Austria. The production of coal in Great Britain during 1901 amounted to 219,046,945 long tons, against 225,181,300 long tons in 1900, a decrease of 6,134,355 long tons during the year, due very largely to depression in the iron and steel and other industries. The coal exported in 1901 amounted to 41,878,345 long tons, against 46,108,011 long tons in 1900, a decrease of 4,229,666 long tons during the year. A royal commission, consisting principally of railway and coal mining experts was appointed early in 1902 to inquire into the extent and available resources of the coal fields of Great Britain. The output of coal in France was 33,404,298 metric tons in 1900, against 32,862,712 metric tons in 1899. The production of coal in Germany and Luxemburg, including brown coal, during 1901, was 152,628,931 metric tons, against 149,788,256 metric tons in 1900, a decrease of 2,840,675 metric tons during the year. The exports of coal, including lignite, during 1901 were 15,287,985 metric tons, against 15,328,600 metric tons in 1900, while the imports of the same products were 14,406,332 metric tons in 1900, against 15,344,362 metric tons in 1900.

India.—While coal is pretty generally distributed throughout India and Burma, five-sixths of the supply comes from the coal fields of Bengal, which produced from 154 collieries in 1895, 3,037,920 tons, all the rest of India producing from 18 collieries but 809,093 tons during the same year. Since that time coal mining in Bengal has increased enormously. The Indian Empire produced from 287 coal mines 6,095,438 tons in 1900, 4,954,965 tons of which was produced by Bengal, at an average selling price of 4s. 5d. per ton.

Japan.—The island of Kinshu furnishes the bulk of the coal supply of the Empire, or about 3,000,000 tons out of a total production of 4,000,000 tons during 1900. The principal coal district lies in the basin of the river Onga, which enters the sea at the port of Wakamatsu. The coal in the upper part of the basin is of superior quality. The Takashima deposits, near Nagasaki, furnish the best coal of Japan. The mine situated in Hizen County, Kumamoto Protectorate, was the first in the Empire to be developed on European lines. The Hiro-Yama mines, in Higo County, are owned by the Kinshu Coal & Railway Co. The famous Miike deposit in Chikugo County is the property of Mitsu & Co., of Tokio. Next to Takashima, the Miike is the best coal in Japan. Four mines in the coal fields on Hokkaido Island are being operated by the Hokkaido Coal Mines & Railway Co. with an annual production of about 1,500,000 tons. The Onodo mines, in Nagato County, Japan Island, furnished an output of about 200,000 tons in 1900, and coal is also being mined to a considerable extent in Ibariki County in the east part of the island.

Mexico.—The coal fields of Las Esperanzas, State of Coahuila, adjoin and run parallel to the Sabinas basin, and are distant about 85 miles southwest of Eagle Pass, Tex. They were discovered in 1899, and development was begun early in 1900 by the Mexican Coal & Coke Co., which owns about 6,000 acres, comprising the only part of the field which is economically workable. The coal is a soft

bituminous coking coal of good quality, and the coal measures are from 6 to 24 ft. in thickness. During 1901 the company built and partially put into operation a block of 224 coke ovens, of which 100 were operated during the latter part of the year, and the balance were started up early in 1902. The Compañia Fundidora de Fierro y Acero de Monterey owns 30,000 acres of land in the Laredo coal field, near Monterey. Anthracite coal is found in the States of Sonora, Michoacan, Vera Cruz, Guerrero, Oaxaca, and Puebla.

THE ANTHRACITE COAL TRADE IN 1901.

BY SAMUEL SANFORD.

THE year 1901 will always be memorable in the history of the anthracite coal trade. Not only was the production the largest on record, exceeding that of 1900 by 24,983,083 tons, but the prices secured have been thoroughly satisfactory to producers. This combination of large output and higher prices is a decided novelty. It was due to a heavy demand and a successful attempt to put the trade on a firmer basis. At the opening of 1901, Morgan interests were in control of 63% of the total tonnage annually shipped out of the anthracite region, enabling them to maintain by strength of position whatever plans they wished. This "community of interests," so-called, had for its working head the Temple Iron Co., a company organized with very liberal charter provisions in 1899. The directors of this company include presidents of all the coal-carrying roads under Morgan control. The company is thus not a trust in the usual acceptance of that term, and cannot be easily reached by any State or United States statutes governing illegal competition or restriction of output. Its directors can discuss policies quietly, there are no necessities for agreements, and harmony is absolute.

The year opened with anthracite in demand. The market had not recovered from the effect of the miners' strike during September and part of October, though the mines in December had shipped something like 5,000,000 tons of coal. Though the weather was mild, activity in the East was greater than for 30 years, while Western trade was also good. The regular prices quoted for free-burning white ash coal, f. o. b. New York, were broken $4, egg $4·25, stove and nut $4·50, pea $3.

During the mild weather of January demand held up well, with the steam sizes and stove and chestnut bringing full circular prices and at some points a premium of 25c. per ton for prompt delivery, though broken and egg slightly declined in prices. February was a month of cold weather and high winds, and the consumption of coal increased. Prices were firm at $3·65 for broken, $4 for egg, and $4·50 for stove and chestnut. March likewise was a cold and stormy month and the consumption of fuel for domestic purposes was very heavy. Prices showed no change. All the coal that the mines could send forward was taken, and by the opening of April supplies everywhere were unusually low. At the head of Lake Superior, docks were bare. Consumers in Chicago territory were taking unusually large all-rail shipments. At inland points East the market was firm and every condition was favorable for an unusually good spring trade. The

various mining and transportation companies issued a spring price list on April 1, which differed materially from any issued before. It named certain prices for the prepared sizes and offered discounts for prompt buying. Thus the New York Harbor f. o. b. prices for free-burning white ash coal, f. o. b. were: Broken $4, egg $4·25, nut and stove $4·50. The steam sizes—pea, buckwheat and rice—were not included, but were to be sold at the discretion of the various companies. The discounts offered from the list prices were 50c. per ton for April, 40c. for May, and so on, till full list prices were in force again, September 1. Another novelty was that sales for forward delivery were abolished. Coal shipped in April received April discounts, but no orders at April discounts were to be taken for May delivery. This change was of particular importance to the Western trade. In addition, discounts to middlemen and jobbers were largely abolished, and prices were made the same to all dealers. It was realized, particularly by the Eastern trade, that back of the list was the power to enforce it. So the price list received respectful attention and brought out considerable early buying by the prudent. Fears of a general strike of the miners on May 1 to secure recognition of their union had doubtless lead to considerable buying during March, beyond that due to the weather. The danger of a strike was removed, however, when the Reading and other companies posted notices about March 12 that the 10% advance in wages granted after the strike of 1900 would remain in force a year longer. Trade during April was generally better, particularly at Eastern points, than had usually been the case in previous years. In the West trade was generally quiet. May began with the demand in the East still good and prices ten cents a ton higher, as per schedule, that is $3·60 for broken, $3·85 for egg, and $4·10 for stove and chestnut, f. o. b. New York Harbor shipping port. Navigation on the lakes was late in opening and a strike of the lake engineers delayed the movement of coal from Buffalo. Buying during the month in the East was liberal, some firms not being able to secure all the coal they wanted at May prices. The movement of coal up the lakes toward the end of the month was heavy. In the East receipts at Boston for the month were 55% greater than in 1900. At the end of May the collieries were working one-half to two-thirds of full time. Supplies in the hands of producers were less on May 31 than on May 1; a most remarkable showing. With warmer weather in June, the market continued surprisingly strong at Eastern points. Buyers in the West apparently did not understand the situation as well as those in the East, though the demand at Chicago from wholesalers was quite active, a most remarkable occurrence. The movement of coal up the lakes continued good. The total shipments from the mines to June 30 amounted to 27,362,187 tons, compared with 22,678,400 tons in 1900, showing the first half year to have been the most active in the history of the anthracite trade.

In previous years, a period of stagnation, known as "midsummer dullness" had usually settled on the coal trade about June 1, lasting until September 1, or even later. In 1901, however, there was no midsummer dullness whatever. A strike of mine firemen affected production in the Wyoming and Lackawanna fields during the latter part of July. The market during August was generally quiet but strong. With prices back to full list figures in September, and the

market good, doubters of the stability of the new order of things were utterly routed. Buying for Western account continued active during September. There were some reports of coal selling for less than list prices, but these reports applied to special grades or conditions and did not affect the market as a whole. By the opening of October most of the collieries were running very nearly full time, with demand good at all points and virtually the only restriction on output was a shortage of cars. This shortage soon became marked and for the rest of the year affected production. By the end of November the Reading collieries and those of some other companies were mining on short time. Demand was strong at both Eastern and Western points. A heavy rain storm in the anthracite region in December did much damage and decreased the December shipments over 500,000 tons. It caused a suspension of shipments on the Lehigh Valley, Central Railroad of New Jersey, and Philadelphia & Reading for nearly two weeks. The year closed with the market very strong and little coal in the hands of producers. The average prices for the prepared sizes of free burning white ash coal for the past two years f. o. b. New York Harbor shipping ports compare as follows:—

Months.	Broken.		Egg.		Stove.		Chestnut.	
	1900.	1901.	1900.	1901.	1900.	1901.	1900.	1901.
January-June	$3·14	$3·88	$3·37	$3·95	$3·72	$4·26	$3·73	$4·99
July-December	3·33	3·94	3·57	4·19	4·07	4·47	4·08	4·47

THE ATLANTIC SEABOARD BITUMINOUS COAL TRADE IN 1901.

BY SAMUEL SANFORD.

EXCEPT for the coal shipped to Boston and a few other points beyond Cape Cod from the mines in Nova Scotia, and a limited amount of Georgia, Kentucky, and Tennessee coal that reaches Charleston and Savannah, the soft coal consumed along the Atlantic seaboard comes from Pennsylvania, Maryland, Virginia and West Virginia. The coal is shipped to tide water from the mines over four railroads: the Norfolk & Western, which carries the product of the Pocahontas and Flat Top fields in southwest Virginia and southeast West Virginia, to Norfolk; the Chesapeake & Ohio, from the New River fields to Newport News; the Baltimore & Ohio, from the Piedmont and Cumberland districts in West Virginia and Maryland to Baltimore; and the Pennsylvania system, which carries to Philadelphia the coal from the Clearfield and the Huntington and Broadtop fields in Pennsylvania, and the Cumberland region in Maryland. These roads are now practically under one control, stockholders in the Pennsylvania Railroad Co. having a controlling interest in the three other lines. The general policy of the Pennsylvania Railroad during 1901 was what had been foreshadowed. The shipments of certain coals were restricted to certain markets. For instance, through freight rates were named, that virtually shut out Pocahontas coal from New York Harbor points—a market that can be supplied with Clearfield. This arrangement reduces selling agencies and shortens rail hauls. While there were no changes in the policies of railroads, there were some very large consolidations of interests in the mining fields, particularly in West Vir-

ginia, which had for their object the securing of more favorable freight rates and a uniform distribution of cars at the mines. In fact, some may be said to act as sales agencies rather than mining companies. A notable purchase late in the year was that of the Flat Top Land Association by the Norfolk & Western Railroad. This purchase is in line with certain other tendencies shown by those in control of the Pennsylvania Railroad. Great activity is to be expected in West Virginia, as the mines nearer tide water are exhausted.

The year opened with the market in fair shape. Such coals as Pocahontas, New River, and George's Creek, were in demand, while Clearfield and the poorer grades were selling slowly; but buying fell off and by the end of the month there was a plentiful supply of even the better grades. The shipping ports were blocked with coal and the railroads were putting embargoes on many producers to keep cars from accumulating at tide water. The Long Island Sound trade was in easier shape than in two years. Freight rates for coast-wise shipments were unusually low. Clearfield coal was selling at $2·40 and $2·65 f. o. b. New York Harbor ports, with better grades at $2·85 and over. The consumption of coal did not keep pace with the amount offered for sale, and there was all through February and into March, an accumulation of coal at tide water. Some lots of low-grade coal, on which demurrage was accruing, sold as low as $2·10 f. o. b. New York Harbor shipping ports.

In March all producers cut their outputs sharply. The Bituminous Trade Association held several sessions in New York City, at which it was given out that the prospect for uniform prices was better than ever, and that everything presaged a successful year for the association. There were rumors of trouble in some of the mining regions during March that probably brought out a little speculative buying, but the danger of a general strike in the Pennsylvania fields passed when the operators agreed to pay a mining rate of 60c. per ton for the year. Late in the month producers announced that they would extend old prices for the coming year. These were as follows: Best grades f. o. b. New York Harbor shipping ports, $2·85; Clearfield, $2·65; best grades f. o. b. Philadelphia, $2·50; Clearfield, $2·35; best grades f. o. b. Baltimore, $2·43; Clearfield, $2·28; New River coal, f. o. b. Newport News, $2·50; Pocahontas f. o. b. Norfolk, $2·50; all prices net to the companies. April opened with the trade still dull, particularly in the far East and along Long Island Sound. The situation did not change materially during May; the better grades were generally firmly held, but the poorer grades were in abundant supply, particularly at Eastern points, and sold at discounts. Heavy arrivals at Boston led to long delays in unloading and considerable coal was sold under demurrage. June found the trade quiet and dull, with tide-water shipping ports still congested with cars waiting for vessels and abundant supplies at most ports beyond Cape Cod. By the end of June conditions began to improve. Prices, however, did not change much, Clearfield at the beginning of July selling at $2·35 f. o. b. New York Harbor shipping ports, while the better grades were $2·85. Trade during July showed very little change. The better grades of coal were firmly held while the poorer grades were in plentiful supply and sold at discounts. By the end of the month labor troubles, which had interfered with industrial activity at many points, were

about over, and as mills resumed, demand improved. By the middle of August a very fair tonnage was going from the mines, particularly for points beyond Cape Cod.

The market continued to improve during September, though the lower grades were still in over supply. By the middle of October trade was in excellent shape. Demand was very heavy, particularly at Long Island Sound points and in all-rail territory, while New York Harbor trade was steadily improving. Car supply at the mines, which, up to the first of October, had been on the whole sufficient, by the middle of the month was less than 50% of the demand, and varied from 25 to 50% for the balance of the year. During November and December the demand for coal at Long Island Sound and New York Harbor points became very pressing, and all grades sold at full circular figures. By the end of the year consumers were regularly paying $4 a ton for spot coal f. o. b. at Long Island Sound ports, and $3·50 a ton at New York Harbor shipping ports, while the coal thus obtained was very often of very inferior quality. In some cases firms in the bunker trade at New York Harbor paid as high as $4 for spot coal.

THE MANUFACTURE OF COKE IN THE UNITED STATES WITH SPECIAL REFERENCE TO THE MARKETS FOR BY-PRODUCTS.

BY F. SCHNIEWIND.[1]

THE manufacture of coke in by-product ovens has now been firmly established in the United States. The long existing aversion against the use of "by-product coke" in blast furnaces and foundries has been dispelled. As a matter of fact, it has been demonstrated on a most extensive scale that the opinion a few years ago prevalent throughout the United States, *viz.*, that the Connellsville beehive coke is a *conditio sine qua non* for modern and economic blast furnace practice, is absolutely without foundation. With the by-product ovens a coke equal and sometimes even superior to the Connellsville beehive coke has been produced from coals which were considered inferior, because they would not coke well in beehive ovens. Furthermore, it has been demonstrated on a large scale that illuminating gas can be obtained as a by-product from coke ovens.

These two achievements forebode the erection of a considerable number of by-product coke ovens, and it is therefore of interest to inquire into the prospects for disposing of the by-products in the American markets.

Before entering upon the description of the coke ovens and statistics of the by-products recovered in the United States some general statistics are given which demonstrate plainly the marvelous development of the industries of the United States. These figures are of considerable interest in connection with the subject, as they bear directly upon the ultimate maximum production of by-products which may occur if the present wasteful methods in the utilization of fuel, coupled with the complete destruction of these by-products, are abandoned. Reference will be made frequently to the corresponding statistical data of European countries in order to obtain from them an idea of the possible extent of the consumption of these products in the United States.

[1] I wish to acknowledge my indebtedness to Mr. C. G. Atwater for his valuable assistance in the revision of this paper.

Coal Statistics.—No other statistics will show the development of the industries in any country so accurately as the consumption of coal, which is the foundation of most industries. By rapid strides the United States has taken the lead among all manufacturing countries, and with the tremendous possibilities presenting themselves in this country, the contingency that any other country may dethrone the United States from its first rank is almost to a certainty excluded. The world's production of coal, including anthracite, bituminous, and lignite, is given on page 128 of this volume, and the graphical chart on page 129 illustrates in a more striking manner the rapid growth of the United States, as compared with the other principal countries. In order to obtain, however, an exact view of the development of the various countries, the imports and exports also should be taken into consideration, and by allowing for these factors the domestic consumption of various countries is as given in the subjoined table, which has been compiled from THE MINERAL INDUSTRY, Vol. IX.

PRODUCTION, EXPORTS, IMPORTS, AND CONSUMPTION OF COAL (INCLUDING COKE) IN THE PRINCIPAL COUNTRIES OF THE WORLD. (SHORT TONS.)

Countries.	Production.	Imports.	Exports.	Consumption.	Consumption per Capita.
United States, 1900	268,242,408	2,296,945	7,606,225	262,935,128	3·46
United Kingdom, 1900	252,107,730	11,143	53,011,224	199,107,649	4·789
Germany, 1900	120,494,054	17,676,952	20,891,491	117,709,515	2·067
France, 1900	36,477,111	16,062,179	1,331,331	51,287,058	1·395
Belgium, 1900	25,783,904	4,101,602	8,087,218	21,748,288	3·259

NOTE.—Allowance is made in the above table for imports and exports of coke. 7 lb. coke is considered as representing 10 lb. coal.

The figures given in the above table do not afford an exact comparison of the various countries, because the United States has other large sources of fuel besides coal, *viz.*, petroleum and natural gas, of which practically none are found in the other prominent industrial countries. The detailed production of coal, petroleum and natural gas in the United States during 1901 will be found under their respective captions elsewhere in this volume. By estimating the coal equivalent for the petroleum produced at 3·22 bbl. (of 42 gal.) per short ton of coal and including an approximate coal equivalent of the natural gas production, the total fuel production (exclusive of wood) should be increased by 19,650,107 short tons of coal for the former and 7,018,000 short tons for the latter, making in all 294,910,515 short tons of total fuel produced in terms of coal.

A revision of the fuel production of the United States in 1900 to include this additional fuel consumption allowing for the exports of petroleum and the imports of natural gas is as follows:—

COAL EQUIVALENT OF MINERAL FUEL CONSUMPTION OF THE UNITED STATES IN 1900. (SHORT TONS.)

Production.	Imports.	Exports.	Consumption.	Consumption per Capita.
294,910,515	2,836,880	14,803,565	282,443,830	3·7

From the foregoing table the quantity of wood used as fuel is omitted because no statistics of its use are available. There should also be taken into consideration the use of electricity generated by water power for light, heat, and power, which is especially important in connection with a large number of electro-metallurgical processes. Under certain conditions electricity is able to displace coal and other mineral fuels, but no statistics concerning its consumption in this special field are available. Among all mineral fuels coal is the chief source of energy, and while the United States occupies the first position in regard to quantity of output, it still must concede to the United Kingdom the first position in regard to consumption per capita.

Uses of Bituminous Coal.—No statistics are available to show the purposes for which bituminous coal is used in the United States, but for the United Kingdom Mr. George Beilby[2] has published a table showing the consumption of coal during 1898 by the various industries in that country from which the following table has been compiled:—

CONSUMPTION OF COAL IN THE UNITED KINGDOM DURING 1898.

	Long Tons.	%
Coal for the generation of power in industries:		
Railways	11,000,000	6·9
Coasting steamers	7,000,000	4·4
Mines	10,500,000	6·6
Factories	39,000,000	24·7
Miscellaneous	8,500,000	5·3
	76,000,000	*47·9*
Coal for the generation of heat in industries:		
Blast furnaces	17,000,000	10·8
Steel and malleable-iron works	11,000,000	6·9
Other metallurgical works	1,500,000	0·9
Chemical works, potteries and glass works	5,000,000	3·1
Gas works	13,000,000	8·2
	47,500,000	*29·9*
Coal for domestic purposes	*35,000,000*	*22·2*
Total	158,500,000	100·0

Of the total amount of bituminous coal (158,500,000 long tons) only a very small percentage is subjected to dry distillation with recovery of by-products, as given in the subjoined table:—

COAL SUBJECTED TO DRY DISTILLATION IN THE UNITED KINGDOM IN 1898.

	Long Tons.
Gas works	13,000,000
By-product coke ovens	1,250,000
Blast furnaces with by-product recovery	2,000,000
Total	16,250,000

This table does not include the coal coked in beehive ovens without the recovery of by-products, which amounts to approximately 12,500,000 long tons. The portion of coal carbonized with loss of by-products is therefore 42·5% of the total coal carbonized, the total being 28,750,000 long tons.

[2] *Journal of the Society of Chemical Industry*, 1899, Vol. XVIII., p. 643.

The conditions in the United States are somewhat different from those in the United Kingdom, as indicated in the following table:—

COAL SUBJECTED TO DRY DISTILLATION IN THE UNITED STATES DURING 1900.

	Short Tons.
Gas works	2,100,000
By-product ovens	1,547,665
Total short tons	3,647,665
Coal coked in beehive ovens (without recovery of by-products).	30,576,790
Coal carbonized with loss of by-products	90% of total.

The amount of coal carbonized in gas works is computed later in this section. The amount of coal coked in by-product ovens is derived from a table showing the manufacture of by-product coke in 1900.[3] The yield of coke in by-product ovens has been assumed at 75%, which may be considered a fair average. The total quantity of coal coked in 1900 was 32,113,543 short tons, and by deducting the 1,547,665 tons mentioned above the amount of coal carbonized in beehive ovens was 30,565,878 tons.

The situation in other countries may differ to some extent, but it is certain that an amazing waste takes place in all countries by destroying the valuable by-products which could be recovered by subjecting the coal to dry distillation before using it. The process of dry distillation of the coal with the production of a smokeless coke and large quantities of illuminating gas and fuel gas suggests itself most forcibly as a solution of the much discussed smoke problem. This subject has been fully treated elsewhere.[4]

Coke and By-Product Ovens.—The development of the coke industry in the United States has kept pace with the general industrial development. The following table[5] shows the number of coke ovens and the production of coke by States:—

COKE PRODUCTION OF THE UNITED STATES FOR THE YEAR 1900.

State or Territory.	Ovens		Coke Produced.	State or Territory.	Ovens		Coke Produced.
	Built.	Building.			Built.	Building.	
			Net Tons.				Net Tons.
Alabama	6,589	690	2,110,837	New Mexico	126	.....	44,774
Colorado (a)	1,488	.....	618,755	New York (b)	30	564	.....
Georgia	480	.....	73,928	Ohio	369	50	72,116
Illinois	154	.....	2,631	Pennsylvania	32,548	2,310	13,799,893
Indiana	54	.....		Tennessee	2,107	340	475,432
Indian Territory	230	.....	38,141	Utah (a)	204	.....	.....
Kansas	91	.....	5,948	Virginia	2,331	300	695,156
Kentucky	458	8	95,532	Washington	90	.....	33,887
Massachusetts (b)	400	.....	....	West Virginia	10,249	1,306	2,359,499
Michigan	.....	30	.....	Wisconsin	120	.....	48,000
Missouri	10	.....	2,087	Wyoming	74	.....	14,501
Montana	342	111	54,731				
New Jersey	.....	100	.....	Total	(c) 58,484	(d) 5,804	20,533,348

(a) Colorado includes production of Utah. (b) Production included in Pennsylvania. (c) Includes 345 Semet-Solvay, 680 Otto-Hoffmann, and 60 Newton Chambers by-product ovens. (d) Includes 150 Semet-Solvay and 948 Otto-Hoffmann by-product ovens.

[3] *Mineral Resources of the United States*, 1900.

[4] "The Production of Illuminating Gas from Coke Ovens," by Dr. F. Schniewind, paper read before the Gas Section of the Engineering Congress at Glasgow. Reprinted in *Progressive Age*, Oct. 15, 1901; and in part in *Iron Age*, Nov. 28, 1901.

[5] *Mineral Resources of the United States*, 1900.

The following ovens were in operation or in course of building in the United States during 1900:—

NUMBER OF COKE OVENS IN OPERATION AND IN COURSE OF BUILDING IN THE UNITED STATES DURING 1900.

(a) By-product ovens:	
Otto-Hoffmann system	1,626 ovens.
Semet-Solvay system	495 ovens.
Newton Chambers system	60 ovens.
	2,181 ovens.
(b) Beehive ovens	62,107 ovens.
Total	64,288 ovens.

The rapid progress of the coke production in the United States during the past five years is evident from the following table, compiled from *The Engineering and Mining Journal*, January 18, 1902, and *The Mineral Resources*, 1900:—

PRODUCTION OF COKE IN THE UNITED STATES AND THE CONNELLSVILLE DISTRICT, 1897-1901.

Year.	United States. Short Tons.	Connellsville District.	
		Short Tons.	Per Cent. of Total Production of United States.
1897	13,288,984	6,860,826	51·6
1898	16,047,209	8,315,350	51·1
1899	19,668,569	10,390,835	52·8
1900	20,533,348	10,020,907	48·9
1901	21,795,883	10,285,943	45·9

The Connellsville district is gradually losing its dominant position as a producer of blast furnace coke. In 1880 it produced 66·1% of the coke supply of the United States; in 1900 only 48·97%. The Connellsville coal basin is being exhausted and other coal fields are being developed which have produced a high grade blast furnace coke in by-product coke ovens.

Quality of Coke.—The coke produced in by-product ovens has proved admirably adapted for furnace use. At the Canal Dover Furnaces, in August, 1900, a test under the direction of Mr. A. E. Uehling of coke made in Otto-Hoffmann by-product coke ovens showed that a ton of iron was smelted with 1,787 lb. of by-product coke, while it required 1,885 lb. of standard Connellsville coke to do the same work, a difference of 98 lb. coke per ton of iron in favor of the by-product coke, or a saving of 5·2% on the coke consumption. At the same time the daily production of the furnace was increased 3·3%. At the Cambria Steel Co.'s furnaces at Johnstown, Pa., a two weeks' series of trials of coke made in Otto-Hoffmann by-product coke ovens from local coals and standard Connellsville coke alternated repeatedly and on different furnaces failed to show any difference in the behavior of the furnaces or consumption of fuel.

The coke has shown equally good results in foundry practice. The product of the Everett ovens has been introduced in railroad and domestic service in competition with anthracite and bituminous coal in the vicinity of Boston, and has met with undoubted success. It is probable that the growing objection to

the presence of soft coal smoke in our cities and the economic impossibility of using hard coal outside of a limited territory will cause a much more general adoption of coke as fuel for domestic purposes, for stationary and locomotive boilers, and in kindred fields.

Pig Iron Statistics.—The production of pig iron in the United States during 1901 was 15,878,354 long tons, which is classified as to the fuel used in its production in the table on page 380 of this volume. The bulk of the pig iron is manufactured with coke as fuel, and approximately one short ton of coke is required for the production of one long ton of pig iron. In connection with the production of coal and coke it is interesting to note the production of pig iron in the principal countries of the world which is best shown by the diagrammatic chart on page 388, elsewhere in this volume.

Another interesting fact in connection with the development of the pig iron industry of the world is the per capita consumption of the principal countries, which has been compiled by Dr. H. Rentzsch[6] as follows:—

PER CAPITA CONSUMPTION OF PIG IRON IN THE PRINCIPAL COUNTRIES OF THE WORLD.

	Pounds.		Pounds.
Austria-Hungary	72·7	Russia	57·3
Belgium	414·4	Sweden	218·2
Canada	92·6	Switzerland	103·6
France	154·3	United Kingdom	418·8
Germany and Luxemburg	359·3	United States	379·1

The above table clearly shows that up to the present time the United States has only reached a per capita consumption of pig iron which places it on a level with the other large manufacturing nations, but it may reasonably be expected that in the future the iron industry of the United States will not only increase in proportion to the increase of population, but even at a greater rate on account of the increasing use of steel in certain branches not so extensively developed in other countries, especially the use of structural steel for office buildings, steel cars, etc.

Illuminating Gas.—According to the *Census Bulletin,* No. 123, the total sales of gas during 1900 (exclusive of coke-oven gas and leakage) was 67,094,000,000 cu. ft. The magnitude of the by-product coke oven industry already established in the United States is evident from the fact that the ovens in operation and in course of erection generate and treat for by-products fully 50,000,000,000 cu. ft. of gas per annum. The annual surplus (not used by the ovens) may be estimated at 15,000,000,000 cu. ft., or about 25% of the annual gas consumption of the country. The following table has been compiled from Brown's *Directory of American Gas Companies:*—

PRODUCTION OF ILLUMINATING GAS IN THE UNITED STATES DURING 1900.

	Cu. Ft.
Coal gas works	8,270,000,000
Water gas works	17,250,000,000
Coal and water gas works	42,628,000,000
Miscellaneous	740,000,000
Total	68,888,000,000

[6] *Stahl und Eisen*, Dec. 1, 1901, and March 15, 1902.

From this table it is apparent that the gas production in the United States, per capita, taking the population according to the Census of 1900 at 76,303,387, is 903 cu. ft., a quantity which is considerably lower than that of the United Kingdom (see page 142). This may be explained to some extent by the very extended use of electric lighting in the United States, and the extensive use of natural gas in certain manufacturing districts, but even with these allowances, the United Kingdom is far ahead of the United States in the per capita consumption of gas.

In recent years the production of coal gas as compared with water gas has considerably increased, chiefly for two reasons, *viz.*: (1) The greatly increased price of oil. (2) It has been recognized that an admixture of coal gas to carburetted water gas is coupled with a considerable reduction in the amount of oil used per candle power, calculated on the blue water gas. As far as may be estimated from the data available the relative proportion of coal and water gas in gas works producing both is 20% coal gas and 80% water gas, therefore the estimated production of coal gas and water gas in the United States during 1900 is as follows:—

COAL GAS AND WATER GAS SOLD IN THE UNITED STATES DURING 1900.

	Coal Gas. Cu. Ft.	Water Gas. Cu. Ft.
Works producing pure coal gas	8,270,000,000	.....
Works producing pure water gas	.....	17,250,000,000
Works producing mixed coal gas (20%) and water gas (80%)	8,526,000,000	34,102,000,000
Total	16,796,000,000	51,352,000,000

It is worthy of note that up to the present time there has been installed by the United Gas Improvement Co., of Philadelphia, sufficient apparatus to produce annually 110,032,900,000 cu. ft. of carburetted water gas.

The amount of gas sold in 1901 and the amount of coal carbonized may be estimated as follows:—

	Cu. Ft.
Coal gas production, 1900	16,796,000,000
Estimated increase for 1901	1,680,000,000
Sales, 1901	18,476,000,000
Leakage, estimated at 8%	1,478,000,000
Coal gas production, 1901	19,954,000,000

As stated above, the coal gas production during the last two or three years has increased rather more than the water gas production, hence the average increase in the coal gas production has been placed at 10%, while the United States Census for 1890 and 1900 shows an increase in the entire gas production of 86·9% for the decade.

The amount of coal consumed (exclusive of boiler fuel) by gas works in 1900 is given in the United States Census as follows:—

	Short Tons.
Coal consumed by gas works (exclusive of boiler fuel)	2,487,287
Coke consumed, 15,214,793 bushels =	304,300
	2,791,587
Coal carbonized	2,100,000
Coal and coke gasified in water-gas plants	691,587

Assuming an average consumption of 28 lb. coal or coke per 1,000 cu. ft. carburetted water gas, the production of water gas in the United States for 1900 was 49,500,000,000 cu. ft. The consumption of oil is given in the United States Census of 1900 at 194,857,296 gal., and assuming an average consumption of 3·75 gal. per 1,000 cu. ft. carburetted water gas, the production of the latter is 51,700,000,000 cu. ft. This production is estimated on the basis of Brown's directory at 51,352,000,000 cu. ft. From the closeness of these estimates they may be assumed as substantially correct.

Production of Illuminating Gas in the United Kingdom.—The Government statistics for the production of illuminating gas in the United Kingdom are published in the *Journal of Gas Lighting*, February 6, 1900, and January 21, 1902, as follows:—

PRODUCTION OF ILLUMINATING GAS IN THE UNITED KINGDOM, 1898-1900.

Year.	Coal Carbonized.	Coal Gas.	Water Gas.	Acetylene Gas.	Total Gas.
	Tons of 2,240 Lb.	Cu. Ft.	Cu. Ft.	Cu. Ft.	Cu. Ft.
1898.....	12,841,817	130,742,718,682	7,404,193,550	82,550	138,146,994,782
1899.....	13,610,688	137,078,455,972	10,077,026,210	76,289	147,155,557,491
1900.....	13,906,288	139,899,277,976	12,108,452,109	81,402	152,007,811,487

The population of the United Kingdom in 1891 was 37,888,000 inhabitants. The consumption of illuminating gas in 1891 was 108,694,259,471 cu. ft. The consumption of illuminating gas per capita in 1891 was 2,869 cu. ft. The population of the United Kingdom for the year 1900 has been given at about 41,454,000, consequently the gas consumption per capita was 3,667 cu. ft., which is a very high average. In the United States the per capita consumption of illuminating gas for the year 1900 was given above, *viz.*, only 903 cu. ft., which, however, excludes the consumption of natural gas.

The Development of By-Product Coke Ovens.

Formerly beehive ovens only were operated for the manufacture of coke, and they still predominate in the United States and in the United Kingdom.

Mon. E. Coppée designed the first successful "retort oven," which found its largest use in Germany, where the firm of Dr. C. Otto & Co. built nearly 8,000 ovens of the "Otto-Coppée" type. These ovens produce a higher percentage of coke than the wasteful beehive oven, and they also reduce the cost of labor.

The next step in the development was the recovery of tar and ammonia. A large number of ovens were designed, but of these the firm of Dr. C. Otto & Co. introduced the most successful types (especially the Otto-Hoffmann regenerative type) and erected in all 4,245 ovens, chiefly in Germany, for the saving of by-products. These ovens are built in the United States by the United Coke & Gas Co., which has still further improved the design especially for the manufacture of illuminating gas.

The number of by-product coke ovens in the United States and Canada is as follows:—

BY-PRODUCT COKE OVENS IN THE UNITED STATES IN 1901.

Company.	Location.	No. of Ovens.	Use of Coke.	Use of Gas.
Otto-Hoffmann ovens:				
Cambria Steel Co. (a)	Johnstown, Pa.	100	Blast furnace	Fuel.
Cambria Steel Co.	Johnstown, Pa.	160	Blast furnace	Fuel.
Pittsburg Gas & Coke Co.	Glassport, Pa.	120	Blast furnace and domestic	Illum. and fuel.
New England Gas & Coke Co.	Everett, Mass.	400	Domestic and locomotive	Illuminating.
Dominion Iron & Steel Co.	Sydney, B. C.	400	Blast furnace	Fuel.
Hamilton Otto Coke Co.	Hamilton, O.	50	Foundry and domestic	Illuminating.
Lackawanna Iron & Steel Co. (a)	Lebanon, Pa.	232	Blast furnace	Fuel.
Lackawanna Iron & Steel Co. (a)	Buffalo, N. Y.	564	Blast furnace	Fuel.
South Jersey Gas, Electric & Traction Co. (a)	Camden, N. J.	100	Foundry and domestic	Illuminating.
Maryland Steel Co. (a)	Sparrow's Point, Md	200	Blast furnace	Illum. and fuel.
Michigan Alkali Co.	Wyandotte, Mich.	15	Burning lime	Fuel.
Sharon Coke Co. (a)	Sharon, Pa.	212	Blast furnace	Fuel.
Semet-Solvay ovens:				
Solvay Process Co.	Syracuse, N. Y.	30	Lime kilns	Fuel.
Semet-Solvay Co.	Dunbar, Pa.	50	Blast furnace	Fuel.
National Tube Co.	Benwood, W. Va.	120	Blast furnace	Fuel.
Semet-Solvay Co.	Ensley, Ala.	240	Blast furnace	Fuel.
People's Heat & Light Co.	Halifax, N. S.	10	Domestic	Illum. and fuel.
Solvay Process Co.	Delray, Mich.	30	Lime kilns	Fuel
Semet-Solvay Co. (a)	Dunbar, Pa.	50	Blast furnace	Fuel.
Detroit Iron & Steel Co. (a)	Detroit, Mich.	135	Blast furnace	Fuel.
Newton Chambers ovens	Pocahontas, Va.	60	Blast furnace	
Total		3,293		

(a) In course of construction.

A Modern Otto-Hoffmann Coke Oven Plant.

In order to adapt the Otto-Hoffmann process, as practiced in Germnay, to the new requirements as presented in the United States, and especially for the manufacture of illuminating gas, many changes were necessary. The following description is of a modern Otto-Hoffmann plant composed of 100 by-product coke ovens, as erected by the United Coke & Gas Co., of New York.[7]

Bituminous coal, when exposed in closed retorts to a high temperature, gives the following products: (1) Coke, remaining as a residue in the retort; (2) tar; (3) gas liquor, from which subsequently by distillation ammonia products are obtained, and (4) coal gas, which contains benzol and its homologues in vapor form. From the gas there are at times additional products extracted—cyanogen and sulphur—but this will not be discussed here.

In order to show the variations in the yields of different coals, the following results obtained on some coals in Otto-Hoffmann coke ovens are given:—

YIELDS OF VARIOUS COALS USED IN OTTO-HOFFMANN OVENS.

Plant Used.	Coke.	Tar.	Ammonium Sulphate.	Total Gas per 2,000 Lb.
Average operating results:	%	%	%	Cu. Ft.
Dominion (Cape Breton) coal, Everett, Mass.	72·88	4·99	1·010	9,000
Youghiogheney (Pa.) coal, Glassport, Pa.	75·60	5·07	1·100	9,000
Westphalian coal (Germany)	74·50	3·70	1·280	9,600
Distillation test:				
Connellsville (Pa.) coal	76·34	6·14	1·228	8,224
Pittsburg (Pa.) coal	68·25	4·38	0·908	8,864
Coal from eastern part of Pennsylvania	85·00	2·00	0·800	8,400
Virginia coal	66·01	4·70	1·070	10,090
Kanawha (W. Va.) coal	73·60	6·40	1·000	10,289

Ovens.—The ovens are arranged in two groups or batteries of 50 ovens each, as illustrated in Figs. 1, 2 and 3. Each oven (1) is an air-tight retort, consisting of a rectangular chamber 43 ft. 6 in. long × 17 in. wide × 6 ft. 6 in. high. The

[7] United States Patents Nos. 627,595, June 27, 1899; 673,928, May 14, 1901; 684,590, Oct. 15, 1901; 698,062, 698,063, Apr. 22, 1902. Further patents pending.

capacity of these ovens is 8 short tons of coal per charge; coking time, 24 hours. The daily coke output, with average coking coal yielding 75% coke, is therefore six short tons. The ovens are placed side by side, and are supported on a steel structure consisting of light I-beams, running the length of the battery, which rest on cross-girders supported by steel columns.

The construction allows the brickwork to be inspected at all points. The primary object, however, is the uniform distribution of fuel gas to the combustion chambers for heating the oven retorts. The retorts are separated by hollow walls, which are divided into 10 compartments (2), each compartment containing four, preferably vertical, flues (3). An air chamber is located directly under the retort (4). Alongside this chamber, and directly under the vertical flues above referred to, are 10 combustion chambers (5). The gas supply to each of the

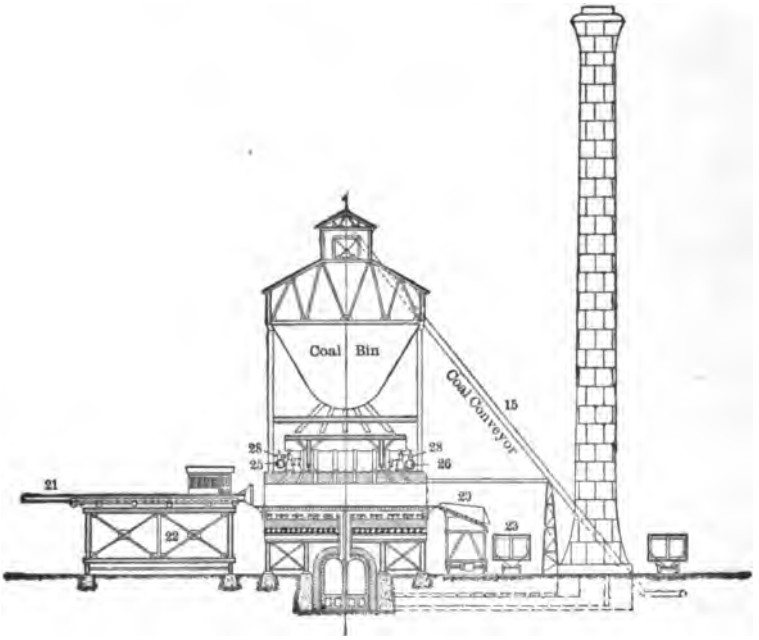


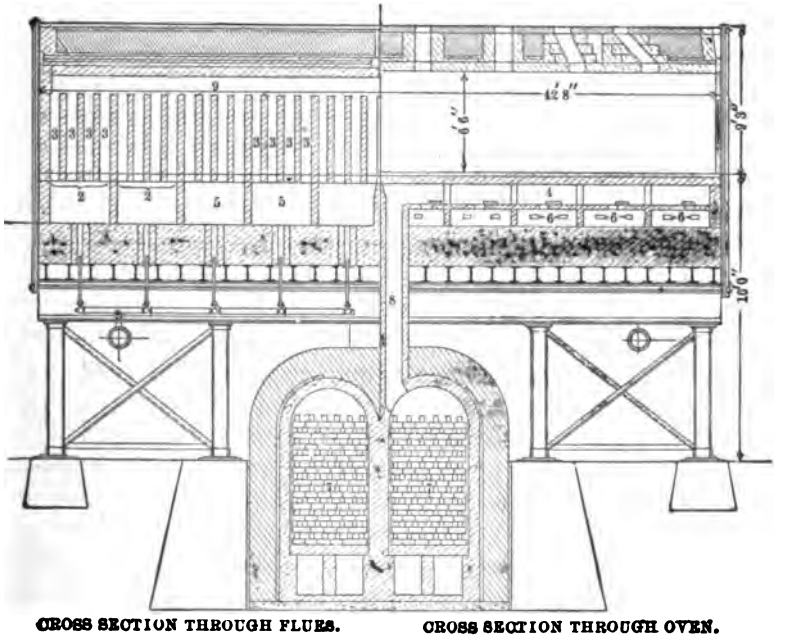
FIG. 1.—CROSS SECTION OF AN OTTO-HOFFMANN BY-PRODUCT COKING PLANT FOR THE MANUFACTURE OF ILLUMINATING GAS.

chambers is controlled independently, and a uniform heat is maintained throughout the entire length of the oven. The air for combustion is admitted through opening (6) in the wall between the air and the combustion chambers. The air is heated to 1,800°F. by a pair of regenerators (7), placed together under the center of the battery and running its entire length. A vertical flue (8) conducts the air from the regenerator to the air-chamber (4), under the oven.

The well-known Siemens principle is used in operating the air regenerators, with reversals every 30 minutes. The fuel gas is reversed at the same time as the air by means of a suitable valve; but the gas is not regenerated. The gas unites with the hot air in five combustion chambers (5), ascends through the vertical flues (3) to a horizontal flue (9) above, through which it passes and descends

through the five chambers in the other end of the oven, thence through the air chamber (4) and vertical flue connection (8) to the regenerator (7) and through the reversing valves to the stack. The regenerators are built entirely independent of the oven structure, so that their expansion does not affect the oven brickwork. Instead of arranging the regenerators directly underneath the ovens, they have been arranged also vertically at the end of the batteries like hot blast stoves.

Coal Handling.—A steel coal storage bin (12) of a capacity equivalent to about two days' coal consumption, is placed between the batteries. The coal is elevated to the bin from a hopper (13), placed under the coal-receiving track (14) by a belt or other type of conveyor (15). A coal larry (16) of 8 tons capacity, runs on a track (17) on the top of the batteries and under the coal bin. The larry consists of a long narrow bin with eight spouts in the bottom, through which



CROSS SECTION THROUGH FLUES. CROSS SECTION THROUGH OVEN.

FIG. 2.—DETAILS OF CONSTRUCTION OF A MODERN OTTO-HOFFMANN BY-PRODUCT COKE OVEN.

the coal is run into the oven retort through holes in the top of it, and is leveled by means of a bar worked through a small opening in the doors at the ends of the oven. The larry is operated by an electric motor and receives its load of coal from the storage bin, under which it passes.

Coal Compression.—A uniformly dense metallurgical coke can be produced, and the output of an oven largely increased by compressing the coal into a mold slightly smaller than the retort and charging the block through the oven door. In order to make a sufficiently solid block it is necessary that the coal should have a certain percentage of water (8 to 12%). Unless the coal carries such an amount it will have to be added. The subsequent evaporation of this water in the coke ovens requires additional gas for heating the ovens; the additional amount

of water vapor has to be condensed (requiring larger condensing capacity) and an increased amount of gas liquor has to be distilled (requiring larger ammonia still capacity). These items form eventually an expense against the saving resulting from the increased capacity of the plant. Generally speaking the answer to the question whether the greater density of the coke is desirable should decide for or against adoption of the coal-compression method. Besides these there are other important points to be taken into consideration which cannot be discussed here.

Coke Handling.—Upon the completion of the coking process the oven doors are raised and the mass of 6 tons of coke is pushed upon a movable platform

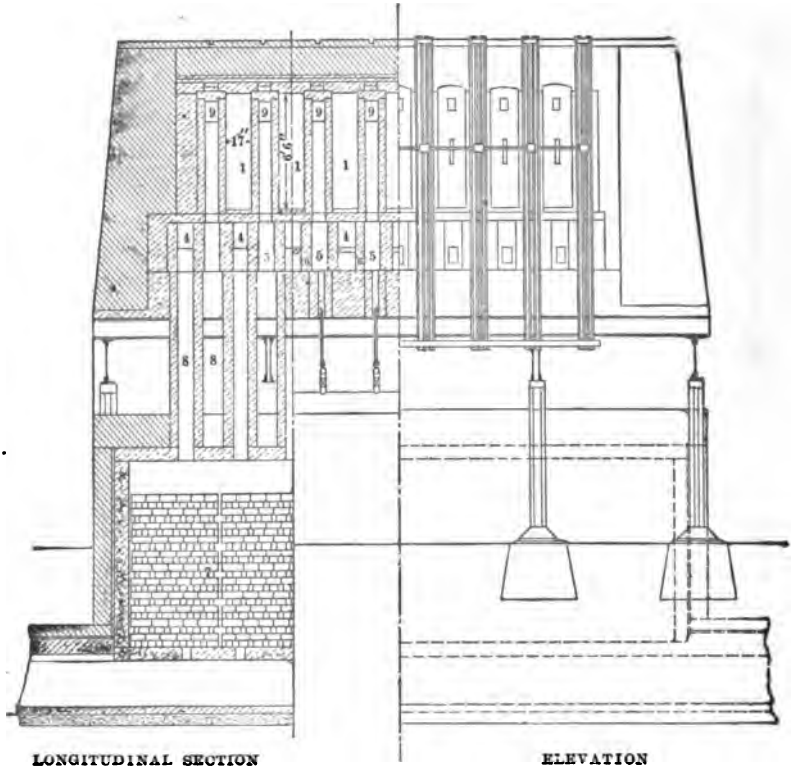


FIG. 3.—DETAILS OF CONSTRUCTION OF A MODERN OTTO-HOFFMAN BY-PRODUCT COKE OVEN.

(20) by means of a ram (21). The pushing ram, as well as the machine (22) on which it is mounted, are operated by electric motors. The coke, after being pushed upon the platform, is quenched and allowed to cool. The platform (20) is then tilted by an electric motor and the coke slides off into cars (23), which run on a track at the back of the machine.

Gas Mains.—The gas distilled from the coal during the coking process is conducted to the condensing house by two independent systems of mains (25 and 26). These mains run on top of the battery for its entire length—one on each side. Each oven is connected to each main by a vertical pipe (27) and valve (28).

During the first part of the process the rich gas is taken off through the rich-gas main (25). The valve to this main is then closed and the balance of the gas is taken off through the poor-gas main (26). When the coking is completed the valve to the poor-gas main is closed, disconnecting the oven from both mains.

Condensing Plant.—The difference in the composition of the two fractions of gas is evident from the following table based upon the Dominion Coal Co.'s Cape Breton coal:—

COMPARISON OF RICH AND POOR GAS FROM DOMINION COAL, OBTAINED IN PRESENT OPERATIONS AT EVERETT.

	Rich Gas (surplus).	Poor Gas (Oven-heating Gas).
	Everett.	Everett.
	% by Volume.	% by Volume.
Illuminants (C_nH_n)	5·0	2·5
Marsh gas (CH_4)	37·4	29·2
Hydrogen (H_2)	44·3	51·8
Carbon monoxide (CO)	6·2	5·0
Carbon dioxide (CO_2)	2·9	2·0
Oxygen (O_2)	0·1	0·4
Nitrogen (N_2)	4·1	9·1
	100·0	100·0
Calorific value B. H. U	707·8	515·0
Candle-power, gas not freed of CO_2	16·3	8·0
Candle-power, gas freed of CO_2	18·5	9·5

The cooling of the gas and the removal of tar and ammonia are done in the usual apparatus, hence it is not necessary to discuss it here in detail. Both the rich and poor gases are treated in the same manner. The following is the sequence of the apparatus as shown in the general sketch of a gas plant for coke ovens, Fig. 4: (1) and (7) are air coolers; (2) and (8) are multitubular water coolers; (3) and (9) are tar extractors; (4) and (10) are exhausters; (5) and (11) are second coolers intended to remove the heat produced by the compression of the gas in the exhausters, and (6) and (12) are ammonia washers.

The rich gas when freed of tar and ammonia, leaves the condensing plant and passes through pipe (42) into the purifying plant (37) and from there into a large storage gas holder for illuminating gas, from which it goes into the city. The poor gas, after being treated in the same manner as the rich gas, leaves the ammonia washers (6) and passes through two benzol scrubbers (13) and (14). After having been freed of its benzol, it flows through pipe (15) into the oven gas holder (16). Here it is mixed with producer gas, when necessary, and carried to the ovens for heating by the pipe (17). The benzol extracted from the poor gas is then transferred to the rich gas, so as to increase its candle-power.

The tar-oil by which the gas is washed runs first from tank (18) through the second benzol scrubber (14) into tank (19). From here it is supplied by pump (19-A) into the first benzol scrubber (13). The tar-oil enters from tank (18) with about 0·5% of benzol, leaves washer (13) with about 1·5% of benzol, and is finally collected in tank (20). From here it is fed by pump (20-A) into still (21) in which the benzol is reduced again to about 0·5%. The exhausted oil collects in tank (22). From here it is taken by pump (22-A) through the oil cooler (23) in order to be again supplied to tank (18) for a new absorption.

A small additional plant is needed (which, however, has been omitted in this sketch), by which a small percentage of the oil is revivified, in order to keep it active for benzol absorption. This consists of a simple tar still and condenser, in which the tar-oil is freed from most of the naphthaline and other hydrocarbons incidentally absorbed. The presence of an excessive percentage of them in the tar-oil would interfere with a complete benzol absorption.

The benzol vapors which are driven off in still (21) are carried into the rich-gas system by means of a gas current coming from the pressure side of the rich-gas condensing plant. This greatly facilitates the distillation of the tar-oil passing through the still. The mixture of the gas and benzol vapors then passes through pipe (24) preferably to the inlet of the exhausters (10) of the rich-gas condensing plant. In this manner, the vapors do not come in contact with a large body of tar, which would be liable to absorb a part of the benzol.

It is unnecessary to describe here the details of the benzol distilling plant.

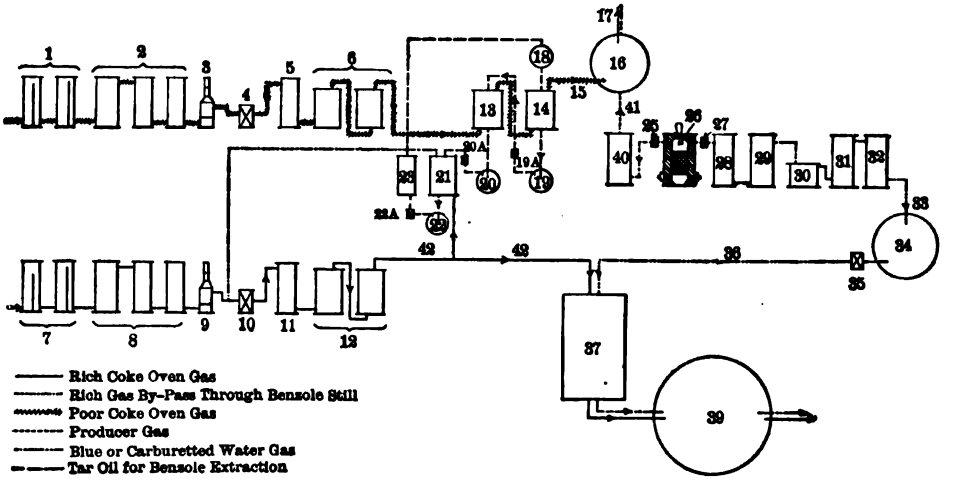

Rich Coke Oven Gas
Rich Gas By-Pass Through Benzole Still
Poor Coke Oven Gas
Producer Gas
Blue or Carburetted Water Gas
Tar Oil for Benzole Extraction

FIG. 4.—ARRANGEMENT OF GAS PLANT FOR BY-PRODUCT COKE OVENS OF THE MODERN OTTO-HOFFMANN TYPE.

A great number of these are in operation in connection with German by-product coke plants. The United Coke & Gas Co., however, controls for the United States the Hirzel process of benzol recovery which has been preferred by the German coke plants.

AUXILIARY GAS PLANT.

When operating the plant continuously, practically the same amount of surplus gas is obtained every day, and the plant would not be adapted to follow the fluctuations in the gas consumption. The plant is consequently so designed that its surplus gas will meet the minimum requirements in summer time, and the increased requirements in winter are made up by an auxiliary gas plant. Two ways suggest themselves in connection with the by-product coke ovens:—

1. *An Auxiliary Producer Plant.*—Producers are operated preferably on coke screenings and refuse coke, which finds a sale only at a reduced price. The pro-

ducer gas thus obtained is mixed with the poor coke-oven gas and burnt under the ovens. In this manner, more rich gas becomes available. Such a plant is now in operation at the New England Gas & Coke Co.'s works, with exceedingly good results in regard to heat efficiency, *i.e.*, 90% of the fuel value of the coke charged into producers is accounted for in the increased volume of rich gas. (This plan has not been shown in the accompanying sketches.)

2. *Auxiliary Water-Gas Plant.*—Instead of a producer plant, a water-gas plant may be added to the coke ovens, as is indicated in Fig. 4. This plant may be operated in three ways:—

(*a*) As a producer plant. By shutting valve (27) permanently and opening valve (25) the generator (26) is permanently used as a producer. A mixture of air and steam is blown through the incandescent fuel bed, and the gas, after being scrubbed in (40) passes through pipe (41) into the oven gas holder, where it mixes with the poor coke-oven gas and is sent to the coke ovens for heating.

(*b*) As a carburetted water-gas plant. By shutting valve (25) and opening valve (27) the plant becomes an ordinary carburetted water-gas plant with generator (26), carburettor (28), superheater (29), washer (30), condensers (31) and (32), and relief holder (34). The carburetted water gas is sent through the exhauster (35), and through the purifying plant (37) into the large storage holder for illuminating gas. It is evident that such an equipment affords a most valuable reserve in case of coal shortage, strikes, etc.

(*c*) Combined producer and water-gas plant. When blowing air through the generator, valve (25) is opened and the producer gas passes through scrubber (40) into the oven-fuel gas holder (16). When the fuel bed thus becomes hot, valve (25) is closed and valve (27) is opened, while steam is blown through the generators. The resulting blue water gas passes through the entire set of water-gas apparatus (28 to 32), while, however, no oil is fed into the carburettor. The blue water gas is finally taken from the storage holder (34) by means of exhauster (35), and mixed with the rich gas coming through pipe (42) at the entrance of the purifying house (37). The mixture of the gas then passes into the storage holder and thence into the city. The candle-power in the rich gas would, of course, be reduced by the admixture of blue water gas, but this is made up by the benzol which is transferred from the poor gas to the rich gas, as described above.

Quality of Gas.—The amount of surplus gas thus recovered is given on page 152. The candle-power and caloric value of the gas are higher than those of the average coal gas. The Everett coke-oven gas has 18 to 19 C.P. without further enriching.

Recovery of Tar and Ammonia.

Tar and gas liquor are obtained in the condensing and scrubbing process through which the gas passes, being collected in large cisterns in which they separate, the havier tar sinking to the bottom. The tar is drawn off and allowed to stand in order to eliminate the water fully, which is facilitated by slightly warming the tar.

The gas liquor is composed of a great number of ammonia compounds for the

enumeration of which reference may be made to the technical literature cited on page 152. The volatile ammonia compounds can be partly driven off from the gas liquor by passing steam through it. The balance of the ammonia is combined with acids in the form of so-called "fixed" ammonia salts which require decomposition by lime before rendering the ammonia volatile in a current of steam.

The general arrangement of the ammonia plant for 100 coke ovens is shown in Fig. 5. It is arranged for the manufacture of both concentrated liquor and sulphate of ammonia. The crude ammonia liquor, which contains between 1 and 3% of ammonia (in accordance with the percentage of water contained in the coal and used in recovery) is pumped from the condensing house cisterns to the ammonia liquor supply tank *S*.

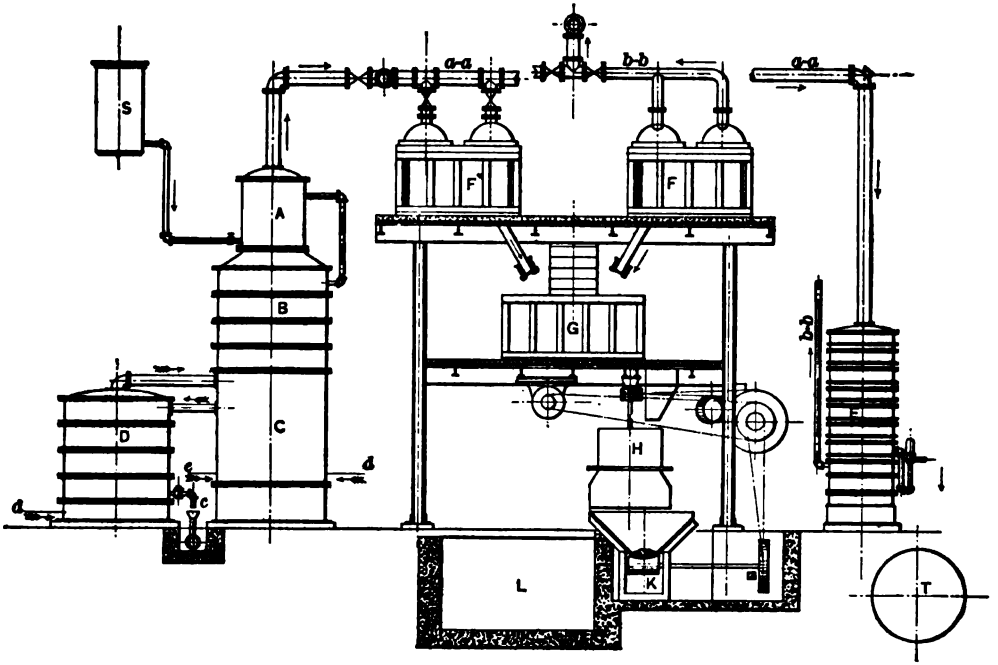


FIG. 5.—APPARATUS FOR MAKING CONCENTRATED AMMONIA LIQUOR AND AMMONIUM SULPHATE.

For the manufacture of concentrated ammoniacal liquor, the liquor from supply tank *S* is run in a constant stream into the preheater *A*, in which it is heated by the ammoniacal vapors and steam given off by the still. The hot liquor enters into the upper part of the volatile ammonia still *B*, where all the volatile ammonia is driven off; it then passes through the lime chamber *C* and lime still *D*, in both of which the fixed ammonium salts are decomposed, the solution finally leaving the lime still at *c* as spent liquor, which should contain but traces of ammonia. The reaction may be expressed as follows:—

$$Ca(OH)_2+2(NH_4)Cl=CaCl_2+2H_2O+2NH_3.$$

The distillation is performed by means of steam, which enters the bottom of lime still *D* and of lime chamber *C*. Milk of lime is introduced into the lower

part of the lime chamber *C* through pipe *e*. The ammonia vapors and steam pass upward through the still proper, breaking in each section through the light seal of liquid, thereby heating the same and driving off the ammonia, until after leaving the upper section of still *B* they enter into the heater *A*, in which they preheat the fresh liquor coming from the supply tank *S*. From the heater the mixture of ammonia vapors and steam, together with volatile impurities (carbonic acid, hydrogen sulphide, etc.) pass through a large pipe line *A* into the concentrator *E*, in which they are condensed by means of cooling water. The ammonia vapors are absorbed by the water and a concentrated liquor is formed, which runs into storage tank *T*. The strength of the liquor can be regulated by the quantity and temperature of the steam used in the stills. The concentrated liquor is forced by means of air compressors into steel tank cars for shipping.[8] The very obnoxious waste gases are brought into the poor-gas mains, and burned under the ovens, or otherwise disposed of in an inoffensive way.

For the manufacture of ammonium sulphate the process is identical with that of concentrated ammoniacal liquor with this difference that the mixture of steam, ammonia vapors and volatile impurities, after leaving the heater *A* are conducted, instead of to the concentrator *E*, to the saturators *F*, which are filled with diluted sulphuric acid. In these saturators, ammonium sulphate is formed with a considerable heat.

$$2NH_3+H_2SO_4=(NH_4)_2SO_4$$

When the sulphuric acid becomes neutralized, the ammonium sulphate separates in the form of white crystals. The salt and mother liquor are finally dropped from the bottom of the saturator into the cooling tank *G* and another saturator is placed in use. After all the ammonium sulphate has crystallized out, it is put through a centrifugal dryer *H*, from which the mother liquor flows into the well *L* and the dried ammonium sulphate drops from the bottom upon a belt conveyor *K*, which brings the market product to the storage room or to the apparatus for automatically weighing it and placing it in bags.

The waste gases from saturators *F* pass through waste gas pipes into the poor-gas main in the same manner as in the manufacture of concentrated liquor. It is necessary, in running the saturator, to cut off the supply of ammonia gas before the point of saturation is reached otherwise loss of ammonia and discoloration of the ammonium sulphate ensues.

Working Results of a Plant of 100 Otto-Hoffmann Coke Ovens.

It is difficult to give a working statement which will apply to all conditions, as the latter may vary considerably with the location. The following items, however, enter into the actual working results and give sufficient data to enable an estimate to be made for any particular condition:—

[8] For the effect of the concentrated ammonia on steel tanks see Pennock & Morton, *Journal of the American Chemical Society*, 1902, XXIV., p. 377.

WORKING RESULTS OF A PLANT OF 100 COKE OVENS AND GAS PLANT.

ANNUAL EXPENDITURE.	Short Tons.
1. *Coal.*—800 net tons of coal per day, or per year	292,000
2. *Wages, materials and maintenance.*—Estimated at 30 to 50c. per short ton of coal carbonized, for which sum the coal is taken from a vessel or railroad car, the coke delivered on the cars and the tar is delivered in a storage tank. The gas liquor is manufactured into concentrated ammoniacal liquor or ammonium sulphate, and the illuminating gas is delivered into the gas holder.	
3. *Gas auxiliary expenses.*—The increased demand of the winter months would be satisfied by means of a producer plant, which would consume of coke. The operating expenses, wages and materials for these producers would amount to about 25 to 40c. per ton of coke gasified. An auxiliary blue water-gas plant, as described above, would entail approximately the same expense.	6,368
4. *General expenses.*	
5. *Interest and depreciation.*—No satisfactory estimate can be made for this item, as the cost of the plant depends greatly on the location.	
ANNUAL RECEIPTS.	
6. *Coke* (75%).—600 short tons per day equal per year. The value of the coke will depend upon the demand for the same. Metallurgical and foundry coke generally command a better price than domestic fuel.	219,000
7. *Tar* (5%) is equal to. Valued at New York at $5 to $7 per short ton.	14,600
8. *Ammonia* (1%) calculated as sulphate. Quoted at present in New York at $60 per short ton. From the sales price, the cost of the sulphuric acid should, however, be deducted, when manufacturing sulphate. 1 lb. ammonium sulphate requires approximately 1 lb. of 60° B. sulphuric acid.	2,920
9. *Additional by-products* (cyanides, light hydrocarbons, sulphur) may be recovered. The market price for these products varies greatly.	
10. *Gas.*—The gas sold to consumers, after taking into consideration the leakage, etc., will amount per year to. The value of the gas in the holder varies according to local conditions within wide limits.	Cu. ft. 1,250,000,000

COAL TAR.

Tar is a product of the destructive distillation of organic substances, and according to the material subjected to this treatment are produced: (1) Wood tar (obtained in the manufacture of charcoal); (2) Oil tar (obtained in the manufacture of carburetted water gas and as a residue in the distillation of crude petroleum); (3) coal tar (produced in the destructive distillation of bituminous coal chiefly in coke ovens and gas retorts. Small quantities of coal tar are also obtained from blast furnaces using bituminous coal, and from by-product gas producers); and (4) Miscellaneous tars (which are obtained by subjecting various organic refuse to destructive distillation, as for instance, bones in the manufacture of bone charcoal. Small amounts of an inferior tar are produced in this way).

The following discussion is limited to coal tar only, including the product from coke ovens and gas retorts and incidentally water gas tar. The quantity of the other kinds of tar produced is so insignificant that it may be neglected.

Statistics.—The following table gives the world's production of coal tar and water gas tar for the year 1900. Accurate figures are not obtainable and the table has been compiled on the basis of the ammonium sulphate and gas produced in the various countries.

THE WORLD'S PRODUCTION OF COAL TAR AND WATER GAS TAR FOR 1901.

	Barrels. (a)	Barrels per Capita.		Barrels. (a)
England	4,000,000	0·096	Belgium, Holland, Sweden, Norway and Denmark	770,000
Germany	2,600,000	0·046	Austria, Russia, Spain and other European countries	880,000
United States	1,200,000	0·016	All other countries	1,000,000
France	840,000	0·023		11,290,000

(a) One barrel of coal-tar=50 gal.=500 lb.

The United States ranks below both England and Germany in the total produc-

tion of tar and its per capita production is even less than that of France. Therefore a large increase in the tar production would not be by any means so serious a matter as has been feared by those averse to the by-product coking system. It is of interest in this connection to glance at the amount of tar and pitch imported into this country, as given by the Bureau of Statistics of the United States Treasury Department.

IMPORTS AND EXPORTS OF COAL TAR AND PITCH IN THE UNITED STATES DURING 1895 TO 1901, INCLUSIVE.

Year ending June 30th.	1895.	1896.	1897.	1898.	1899.	1900.	1901.
	Barrels.	Barrels.	Barrels.	Barrels.	Barrels.	Barrels.	Barrels.
Imports of tar and pitch	116,630	141,515	111,526	86,602	25,049	74,285	37,959
Exports of tar	22,773	16,865	17,640	19,316	36,903	36,535	.....

The imports and exports of tar are insignificant when compared with the production, particularly in recent years.

Of the 74,385 bbl. of tar imported into the United States in 1900, 71,980 bbl. came from the United Kingdom. The extent to which the other derivatives of coal tar are imported into this country is also to be taken into consideration. These products, comprising benzol, toluol, carbolic acid, salycilic acid, aniline and alizarine colors and dyes, and numerous other technical and pharmaceutical articles, were imported to the value of $6,773,152 in 1900, on which duty to the amount of $1,516,689 was paid.

The English market reports as given in the *Journal of Gas-Lighting* show that the average annual price of tar has varied from 1·57c. to 2·27c. per U. S. gal. since 1895, the average price for 1901 being 1·74c., and that pitch has varied from $5·73 to $10·47 per short ton; the average price for 1901 being $8·49. The prevailing price for the tar in the United States ranges between 2·5c. and 3·5c. per gal. in large quantities. The German prices are somewhat above the English prices, and approach the American figures. Large quantities of crude tar products are imported by Germany from England. Germany, as is well known, leads all other countries in the manufacture of refined tar products, as is instanced by the fact that one-third of the crude carbolic produced in England is sent to Germany for refining.

Composition—Crude tar varies considerably in its quality, the differences arising partly from the coal from which it is derived and partly from the method of distillation. The distinguishing characteristic of coke oven tar is its low percentage of free carbon, which varies from 8 to 15%, while tar from gas works commonly has from 20 to 35% and even more, due to the higher heat used in carbonization which tends to destroy the hydrocarbons. The low percentage of free carbon in coke oven tar increases its value for most purposes, especially in the chemical industry. Characteristic analyses of coke-oven tar and gas-house tar are given in the table on page 154.

Uses.—Crude tar is used directly without further treatment for a number of purposes and a certain proportion of the production is absorbed in supplying these demands. A number of the smaller gas works, particularly in England and the United States, find disposition for their whole product in local fields for

DISTILLATION TESTS OF VARIOUS COAL TARS. (a)

Fractions.	Coke-oven Tar.		Gas-works Tar.		
	Dominion Coal. (Everett.)	Germania Plant (Westphalia).	German.	American.	
				Fair Quality.	Poor Quality.
	%	%	%	%	%
Light oil	1·26	6·55	2·5	1·65	6·14
Middle oil	14·78	10·54	2·5	10·66	5·08
Heavy oil	7·07	7·62	25·0	8·18	7·50
Anthracene oil	21·38	44·35	10·0	14·05	11·71
Pitch	53·08	30·55	60·0	61·16	68·25
Water	1·52	Trace.	.....	1·81	.....
Loss	1·01	0·39	.....	2·48	1·37
Total	100·00	100·00	100·0	.....	100·00
Free carbon	8-10	.....	25	.....	48·4
Specific gravity	1·188	1·1198	1·155	.....	1·255

(a) White & Hess, in *Journal of Chemical Industry*, 1900, p. 509.

painting, varnish making, pipe coating, dipping paving brick and roofing tile, preserving stone work, concrete pavements, etc. The manufacture of tar varnish consists principally in heating the tar to drive out the ammoniacal liquor, which would corrode iron work, and in thinning the tar by the addition of oil. The market for this product is limited, as a similar article, usually better adapted to its specific purpose, is made by the large tar works, by mixing hard pitch and light oils with other ingredients to suit various requirements. A certain amount of crude tar is also used for the basic lining of Thomas and Gilchrist steel converters, but the consumption in the United States for this purpose is very small. The use of crude tar as a fuel is also met with from time to time. Market conditions and the difficulties of transportation have in times past caused the burning of a great deal of tar, but of late years the development of the tar industry has precluded this. Numerous determinations have been made of the fuel value of tar for steam raising and other purposes. The theoretical calorific power of tar compared to coal was estimated by Mr. F. G. Dexter as 2 to 1.[10] Lunge[11] considers this value high and cites a test by Mr. J. T. Lewis, showing a ratio of 7 to 5 between tar and coke burned under gas retorts. Körting[12] gives the theoretical value as 1 to 1·2 but states that the practical efficiency will favor the tar. Mr. C. F. Prichard[13] gives the calculated calorific power of coal tar as 15,781 B. T. U. per lb. and coal as 14,385 B. T. U., a ratio between the theoretical values of about 1·1 to 1, while the actual test showed that the evaporative effect was as 11·91 to 9·8, a ratio of 1·21 to 1. The latter test Mr. Prichard does not consider as conclusive for the tar, but he believes that a ratio of 14 to 9·8 or 1·43 to 1 should be easily attained. This is practically the same as Mr. Lewis's ratio of 7 to 5 (1·4 to 1).

Tar (or preferably tar oil) when burned in a specially constructed furnace with insufficient air supply yields lamp black. The products of combustion are led through long brick passages before reaching the stack, and in these the soot is deposited. Lamp black is used in the manufacture of printers' and lithographers' ink, patent leather, and in making carbon electrodes.

[10] *Journal of Gas Lighting*, 1866, p. 1242.
[11] *Coal-tar and Ammonia*, p. 237.
[12] *Journal fuer Gasbeleuchtung*, 1886, p. 543.
[13] *Proceedings of the American Gas Light Association*, Vol. XVIII., 1901, p. 389.

Saturated felt paper is made by passing dry felt through hot tar, then through squeezing rollers, and then winding it up in rolls of the desired size, which are allowed to dry out before placing on the market. Felt, according to its nature and to that of the tar, will absorb from 75 to 150% of its weight. Two- and three-ply papers are made by passing two or three layers of saturated felt between heated rolls, at the same time adding hot pitch of the proper consistency to cement the inner surfaces together. Some papers are even supplied with a layer of gravel imbedded in pitch on one side, and are called "ready roofing." The saturated felt is usually applied to the surfaces to be water proofed, in successive layers, each being painted with hot pitch, which cements the whole together. If used on roofs a final layer of gravel is spread over the surface. For water proofing brick work or concrete foundations, the outer shell of the structure is built, and then lined with the saturated felt and well pitched, after which the inner masonry is built up.

Coal Tar Distillation.—Coal tar is ordinarily distilled by heating it in steel vessels enclosed in brick work settings which are provided with grates for burning coal. The vapors given off are condensed in a coiled pipe or worm immersed in water. The distillates flow into a small receiving tank which discharges into storage tanks provided for the different fractions; the oil usually being separated in accordance with its specific gravity. The pitch remaining is transferred from the still to a cooler, from which it flows into barrels when cooled to the proper temperature. The usual form of still is a horizontally-placed cylinder of boiler plate. The larger ones hold about 10,000 gal. and the smaller ones are of various capacities down to 500 gal. European tar distillers generally use a vertical still with concave bottom. In American practice the distillates given off below 270°C. (518°F.), are usually separated into light and heavy oils only (*i.e.*, oils of a lower or higher specific gravity than water). With the light oils, a more or less considerable amount of water is expelled, so they are collected in a storage tank and separated after settling. It is not usual to separate the fractions more carefully, though in some cases redistillation of the light oil for "naphtha," etc., is carried on. The heavy oils or creosote oils are used largely in wood impregnation, and for the manufacture of lamp black.

In European works, the distillation is carried much further, *i.e.*, to a higher temperature than in the American plants, the object being to obtain the anthracene oil, which is the basis of the very extensive alizarine dye industry. The following scheme of the distillation process is given by Schilling.[14]

Temperature of Distillates.	Commercial Product.
I. Fraction up to 338° F.	Ammoniacal liquor, 90% benzol, 50% benzol, solvent naphtha, burning naphtha.
II. Fraction 338° to 446° F.	Naphthalene, carbolic acid.
III. Fraction 446° to 518° F.	Creosote oil for impregnation, lubricating oil.
IV. Fraction 518° F. upwards.	Anthracene
V. Residue.	Pitch.

In European works the distillation is usually carried on under a slight vacuum, and the separation of the various oils is done by a measuring device. The temperature is carried as high as 360°C. (680°F.), which is about as high as the

[14] *Gas-Beleuchtung*, p. 226.

stills will stand. The resultant pitch which is much harder than the American product is run into depressed pitch floors to cool and is afterward broken up into pieces for shipment in bulk. It is chiefly used in the briquette industry. If a soft pitch is required, the hard pitch is remelted (or "cut back") with heavy oil, or the heavy oil is added to the pitch while it is yet molten in the still. A large portion of the soft pitch used in England and on the Continent is made in this way.

Numerous attempts have been made to avoid the difficulties incident to the operation of the ordinary intermittent tar still by developing a continuous process and a number of devices for the purpose are mentioned by Lunge in his work, *Coal Tar and Ammonia,* p. 334, of which those introduced and operated by Lennard in England, and H. Hirzel at Leipzig, appear to have met with some measure of success. The Lennard still, of which in 1895 there were three in Great Britain and one on the Continent, has a capacity as high as 480 bbl. per day.

Soft pitch is extensively used in paving to fill the interstices in brick, stone or wooden pavements. It is also used in asphalt pavements to some extent. Pitch by itself is very much used in certain sections of the country as a binder for concrete, and gives very general satisfaction where traffic is not too severe. A form of pavement called tar macadam has lately come into prominence. It is a combination of broken stone and soft pitch mixed hot and rolled in place under a heavy roller. Very good results have been reported from its use.

Briquetting.—The manufacture of fuel briquettes is the principal use for coal-tar pitch in England and on the Continent. The high price of fuel and the fact that there are large quantities of fine coal of little or no value has caused this development. The subject has been thoroughly discussed in THE MINERAL INDUSTRY, Vol. VI., to which reference should be made. It is possible that the increase in the number of by-product coke ovens and the consequent larger supply of tar and pitch, together with the growing demand for a convenient and smokeless fuel may cause the industry to make more progress in the United States than it has done hitherto.

Tar Chemicals.—The chemicals recovered from tar distillation are the benzols (50 and 90%), solvent and burning naphtha, pyridine basis, carbolic and cresylic acid, naphthalene, creosote oil, anthracene, etc. The development of the tar chemical industry has been carried farther in Germany than elsewhere, and the concerns engaged in it have been very prosperous.

AMMONIA.

Distribution of Nitrogen in Products of Dry Distillation of Bituminous Coal.—The nitrogen contained in bituminous coal is the most important source of ammonia, and in the near future it will doubtless become the most important source of combined nitrogen. Dr. Knublauch[1] found the distribution of

[1] *Journal fuer Gasbeleuchtung*, 1895, p. 756. Similar investigations are published by Wm. Foster, *Journal of the London Chemical Society*, 1883, p. 105, and L. T. Wright, *Journal of Gaslighting*, Vol. LII., p. 169, in which latter publication the great influence of the temperature is shown. H. Tichauer, *Journal fuer Gasbeleuchtung*, 1894, pp. 363 and 381.

nitrogen in the products of dry distillation of two Westphalian coals to be as follows:—

DISTRIBUTION OF NITROGEN IN PRODUCTS OF DRY DISTILLATION OF WESTPHALIAN COALS.

	I.	II.
Of 100 parts nitrogen in the coal were found:	%	%
In coke	30·0	35·6
In gas liquor as ammonia	11·9	14·1
In cyanides	1·8	1·8
In tar	1·3	1·4
As free nitrogen in gas and rest not determined	55·0	47·1
Total	100·0	100·0
Nitrogen in the coal	1·55	1·479

It is therefore seen that only about 13% of the total nitrogen in the coal is obtained in form of ammonia. The Mond producer gas process recovers a part of the large percentage of nitrogen remaining in the coke.

The percentage of nitrogen in coal varies from 0·5% to 2·5%, and ordinary coking and gas coals contain from 1·5% to 2·0%.

A large number of processes have been suggested for the increase of the ammonia yield in the dry distillation of coal, among which the addition of lime to the coal has been proving advantageous, as far as the increase in the yield is concerned. Its use, however, is coupled with serious disadvantages which have prevented its adoption in practice.

Gas Liquor.—The amount of gas liquor obtained varies between 7% and 15% according to the percentage of moisture and water of decomposition as well as with the amount of additional scrubbing water used. It does not contain any ammonia in the free state, but is a mixture of various compounds in widely varying percentages of mixture. As an example of its composition the analysis of an English gas liquor is quoted from Arnold, *Ammonia and Ammonia Compounds,* which however should by no means be considered as an average analysis.

ANALYSIS OF AN ENGLISH GAS LIQUOR (BY DYSON).

Ammonium sulphocyanide	$(NH_4)CNS$	0·180%
Ammonium sulphide	$(NH_4)HS$	0·308%
Ammonium sulphate	$(NH_4)_2SO_4$	0·019%
Ammonium thiosulphate	$(NH_4)_2S_2O_3$	0·260%
Ammonium chloride	$(NH_4)Cl$	1·428%
Ammonium ferrocyanide	$(NH_4)_4Fe(CN)_6$	0·041%
Ammonium carbonate	$(NH_4)_2CO_3$	3·916%
Total ammonia	NH_3	2·045%
Total sulphur	S	0·392%

A few of these compounds are decomposed by steam (volatile ammonia), ammonium carbonate, for instance, splits up as follows:—

$$(NH_4)_2CO_3 = 2NH_3 + H_2O + CO_2.$$

Others are decomposed only by an addition of a stronger base than ammonia. For instance, ammonium chloride reacts with lime as follows:—

$$2(NH_4)Cl + CaO = CaCl_2 + H_2O + 2NH_3.$$

The relative proportions of fixed and volatile ammonia vary considerably, according to the character of the coal from which the gas liquor is derived.

Various Ammonia Products.[2]—The quantity of the various ammonia products consumed in the United States is given elsewhere in this section. Ammonia is shipped from the coke works generally as ammonium sulphate or concentrated ammonia liquor which form the basis for the production of the other ammonium compounds. Gas works in the United States generally sell the gas liquor in its crude state.

Ammonium Sulphate.—Ammonium sulphate is a white salt produced by passing ammonia vapors through sulphuric acid. The commercial article contains between 24 and 25% of ammonia (NH_3), or from 19·8 to 20·6% nitrogen; its purity depends chiefly on the purity of the sulphuric acid used.

The coke-oven sulphate is very pure and is generally sold on a guarantee of 25% of ammonia (NH_3). It is very hygroscopic and consequently has to be stored in dry places. It is usually shipped in bags of 200 lb., and in the manufacture care must be taken that there is no excess of free acid in the salt which would quickly destroy the bags. It is used chiefly as a fertilizer and as raw material for other ammonia products. The presence of small amounts of impurities (iron and cyanides, metallic sulphides, etc.) often causes more or less discoloration of the otherwise white or grayish salt. This is the cause of (unfounded) objection by the manufacturer of chemicals, while the color makes no difference to the manufacturer of fertilizers. In case the sulphate is to be used for the manufacture of anhydrous ammonia it should contain as little of pyridine and other tarry impurities as possible. Formerly ammonium sulphate was often made by neutralizing the gas liquor with sulphuric acid and evaporating the weak sulphate solution. This salt was very impure and contained more or less ammonium sulphocyanide, which is very objectionable in case the sulphate is used as a fertilizer, because it is poisonous to plants. With the manufacture of ammonium sulphate as now practiced, *viz.*, by distillation of the crude liquor, the presence of this substance is completely avoided.

Concentrated Ammonia Liquor.—Concentrated ammonia liquor is produced by condensing the mixture of steam, ammonia and gases which are leaving the ammonia still. It is chiefly a solution of ammonium carbonate and ammonium sulphide and is generally guaranteed to contain a minimum of 15% of ammonia, but the percentage of ammonia varies between 15 and 20%. It is shipped in tank cars and is used chiefly in the manufacture of soda from salt (brine) by the ammonia process. It is also used as a raw material for the manufacture of other ammonia products and its use for this purpose may increase considerably, because it can be bought cheaper than sulphate on account of the saving of the expense for sulphuric acid. For many years there has been a great scarcity of ammonia in this country, which accounts for the slow development of the manufacture of soda, but with the increasing ammonia supply this industry has rapidly developed.

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[2] THE MINERAL INDUSTRY, Vol. VII., "Ammonia and Ammonium Sulphate," by Mr. H. A. Frasch; Dr. G. Lunge und Dr. H. Koehler, *Die Industrie des Steinkohlentheers und Ammoniaks*, Fourth Edition, 1900, which has been translated into English; Dr. G. Lunge, *Coal Tar and Ammonia*, Third Edition, 1900; Dr. B. Arnold, *Ammoniak und Ammoniakpraeparate*, 1889, translated into English, *Ammonia and Ammonium Compounds*; A. Fehrmann, *Ammoniakwasser*, 1887; Camille Vincent, *Ammonia and its Compounds*, 1901; Weill-Goetz et Desor, *Eaux Ammoniacales*, 1889; P. Truchot, *L'Ammoniaque* (without date).

In this connection the following list[3] of soda manufacturers, which does not include those making this product electrolytically, may be of interest:—

SODA WORKS IN THE UNITED STATES USING THE AMMONIA PROCESS.

	Capacity in 1900.	Extensions in Course of Erection.
(1) Solvay Process Co., Syracuse, N. Y.	600	.....
(2) Solvay Process Co., Delray, Mich	250	250
(3) Michigan Alkali Co., Wyandotte, Mich	500	.....
(4) Mathieson Alkali Works, Saltville, Va.	150	.....
(5) Columbia Chemical Co., Barberton, O.	200	.....
(6) Frasch Process Soda Co., Cleveland, O.	30	.....
	1,730	250
		1,730
Total	.....	1,980

Lunge[4] states that the loss in the manufacture of 100 tons of soda ash is about one ton of ammonia expressed as sulphate. Consequently the manufacture of 2,000 tons of soda ash per day would consume daily the equivalent of 20 tons of ammonium sulphate. We may estimate, therefore, the annual requirements of this country in the soda industry as equivalent to about 6,000 short tons of sulphate.

Caustic Ammonia or Aqua Ammonia.—This is produced by redistilling the concentrated gas liquor and removing all the impurities (carbonic acid, hydrogen sulphide, tarry constituents, etc.). It is therefore a concentrated solution of pure ammonia. It contains from 20 to 35% of ammonia (NH_3). Formerly it was extensively used for refrigerating purposes, but it has recently been replaced to a great extent by liquefied anhydrous ammonia. It is now used in the textile industries for dyeing, for domestic purposes, for electroplating, for chemical purposes, in laboratories, etc. The price varies according to strength and purity. No statistics are available of the quantity of ammonia consumed in this form. It is generally shipped in iron drums of about 1,000 lb. capacity.

Considerable quantities of caustic ammonia are used in the manufacture of potassium cyanide by means of recent processes,[5] one of which has been introduced into this country, and a very considerable amount of ammonia is consumed. In Germany anhydrous ammonia is used instead of caustic, which is preferable for many reasons, but the present price of anhydrous ammonia makes its use for this purpose in the United States too costly.

Aqua ammonia often contains up to 2·5 g. pyridine per liter, which becomes troublesome in making anhydrous ammonia from it. Its determination is described by J. D. Pennock and D. A. Morton.[6]

Anhydrous Ammonia.—Ammonia gas is produced commercially, either by the distillation of concentrated ammonia liquor, in which case lime and copperas are added in order to retain the carbonic acid and hydrogen sulphide and subsequent cooling, purifying and drying of the ammonia gas, or by the decomposition of ammonium sulphate with caustic lime under heat:—

$$(NH_4)_2SO_4+CaO=CaSO_4+H_2O+2NH_3.$$

[3] *Chemical Trade Journal*, Jan. 18, 1902.
[4] *Manufacture of Sulphuric Acid and Alkali*, Vol. III., p. 121.
[5] *Journal of Franklin Institute*, 1902, p. 72.
[6] *Journal of the American Chemical Society*, 1901, p. 385.

The ammonia gas is carefully freed of moisture and all impurities and is then liquefied by compression. It is generally shipped in iron flasks holding about 100 lb. each. It has been found that anhydrous ammonia manufactured from coke oven sulphate contains but very little of the undesirable pyridine bases. The present price of anhydrous ammonia is about 25c. per lb. f. o. b. ammonia works. According to *United States Census Bulletin* No. 174, p. 9, the price during 1900 varied from 22 to 40c. per lb. (on an average, 26·4c.), according to the distance from the source of supply. It is chiefly used for refrigerating purposes and in the manufacture of artificial ice.

Refrigeration and Ice Manufacture in the United States.—Artificial refrigeration has developed in the United States to an astonishing degree, so that this industry has become the outlet for large quantities of ammonia. A number of processes have been invented which were based upon the use of materials other than ammonia, *i.e.*, sulphurous acid, ether, etc., but they have been unable to compete with the ammonia process, which is operated either by the compression system, using anhydrous ammonia, or the absorption system, using aqua ammonia.

Artificial refrigeration is used for the manufacture of ice and for the production of cold in breweries, meat and provision packing houses, chemical factories, etc.

The combined capacity of all refrigerating and ice-making machinery in the United States is estimated at 200,000 tons of refrigeration per day. This estimate has been based upon the numbers and size of the machines built by the various manufacturers.

The loss of ammonia varies considerably, but we may assume as an average figure 20 lb. ammonia (NH_3) per annum for each ton of daily refrigerating capacity (40 lb. per ton ice-making capacity). On this basis the present annual requirements are equal to 2,000 short tons of ammonia (or 8,000 short tons ammonium sulphate).

The *United States Census Bulletin* No. 174 gives interesting statistics compiled by A. L. Hunt on the manufacture of artificial ice, which constitutes only a part of the refrigerating capacity of the United States. Nevertheless they may well be taken as an index of the growth of the refrigerating industry:—

NUMBER OF ACTIVE ICE PLANTS IN THE UNITED STATES. (*a*)

	1870.	1880.	1890.	1900.
New England States	.....	.....	.....	7
Middle States	.....	.....	14	169
Southern States	4	29	165	886
Central States	.....	1	23	152
Western States	.....	.....	7	40
Pacific States	.....	5	13	33
Total in United States	4	35	223	787
Capital invested	$434,000	$1,251,200	$9,846,468	$38,204,054

(*a*) United States Census statistics.

This development is especially noteworthy in that the progress in the Northern States indicates that artificial ice is now successful in its competition with natural ice.

The amount of ammonia consumed is given at 1,056,535 lb. anhydrous (costing on an average 26·4c. per lb.) and 1,323,454 lb. aqua (costing on an average 6c.

per lb.). Taking the latter at 20% ammonia (NH_3) we would find that the total ammonia consumption has been equivalent to 660 short tons anhydrous (or 2,640 short tons ammonium sulphate) in the manufacture of ice alone. The ice production during 1900 was 4,294,439 short tons. Calculating from these figures the annual ammonia consumption for each ton of ice-making capacity per day is 112 lb., which figure is considerably higher than that found above in the computation of the refrigerating ammonia consumption in the United States. It must be borne in mind, however, that these ice plants comprise the majority of the smaller and less economical works.

Other Ammonium Compounds.—The following ammonium compounds are of commercial importance: Ammonium chloride (muriate of ammonia), ammonium carbonate, ammonium nitrate, ammonium picrate, ammonium sulphocyanide (rhodanate of ammonia), and ammonium phosphate. Also, but of minor importance, ammonium chromate, ammonium acetate and ammonium oxalate.

Sources of Ammonia Supply.—The domestic ammonia production of the United States until recently has been derived almost entirely from coal gas works, but this supply is becoming entirely inadequate. In recent years by-product coke ovens have been adopted and there are fair prospects of their rapid introduction. This is the only source of domestic ammonia supply which promises a considerable increase.

In England ammonia has also been recovered from the Mond gas producers, from the shale-oil industry, and from certain blast furnaces operating on bituminous coals. Small quantities are also obtained in abattoirs and bone charcoal factories. No great increase may be expected from these sources. The largest part of the world's production of ammonium sulphate is used as a fertilizer, a field in which enormous quantities of sodium nitrate are consumed. The addition of the statistical data for the latter may therefore prove of interest.

The following table shows the world's production of ammonium sulphate and exports of sodium nitrate from Chile, the latter being practically identical with

WORLD'S PRODUCTION OF AMMONIUM SULPHATE AND SODIUM NITRATE. (*a*)
(IN METRIC TONS.)

	1898.	1899.	1900.	1901.
Ammonium sulphate:				
Great Britain	196,500	208,000	210,000	220,000
Germany	100,000	110,000	120,000	130,000
United States	49,000	52,000	58,000	60,000
France	35,000	36,000	37,000	38,000
Belgium, Holland, Sweden, Norway and Denmark	30,000	32,000	33,000	35,000
Austria, Russia, Spain, and other European countries	30,000	30,000	35,000	40,000
Total production	440,500	468,000	493,000	523,000
Sodium nitrate:				
Exports from Chile	1,365,000	1,370,000	1,430,000	1,270,000
Nitrogen equivalent in metric tons of world's sulphate production	87,220	92,600	97,610	103,550
Nitrogen equivalent, in metric tons, of Chile's nitrate exports	197,970	214,400	223,800	198,760
Total	285,190	307,060	321,410	302,310
Percentage of sulphate	30·6%	30·2%	30·3%	34·3%
Price of 2,000 lb. nitrogen at Liverpool, in—				
Sulphate (10,101 lb.)	$208·80	$248·20	$244·15	$222·50
Nitrate (12,779 lb.)	191·05	222·10	235·50	249·40

(*a*) *Zeitschrift fuer Angewandte Chemie*, April 23, 1901: *L'Engrais*, Jan. 24, 1902; Annual Report of the German Sulphate Syndicate for 1901.

the world's production. This table shows (1) that the nitrogen equivalent of the sulphate production is only about one-half that of sodium nitrate. (2) That the production of sulphate has been constantly increasing even during the period when the price of its nitrogen equivalent was higher than that of nitrate. The progress will doubtless be continued.

Production and Consumption of Ammonia and Nitrate in the United Kingdom.—By reference to tables elsewhere in this volume it will be seen that the United Kingdom is the only exporting country; all others obtaining their deficiencies from Great Britain. This is for two reasons, *viz.:* (1) The consumption of gas per capita is larger than in any other country and almost all the gas is coal gas, which accounts for the large production of sulphate, and (2) the English farmer is slow in recognizing the value of ammonium sulphate as a fertilizer.

In both instances, however, there are movements on foot which tend to reduce the available surplus. Water gas is making rapid advances[7] and the domestic consumption of ammonium sulphate is also increasing, due to the energetic propaganda of the British Agricultural Stations and the Sulphate of Ammonia Producers' Association.

STATISTICS OF AMMONIUM SULPHATE PRODUCTION AND CONSUMPTION OF THE UNITED KINGDOM FROM 1895 TO 1901, INCLUSIVE. (*a*) (LONG TONS.)

	1895.	1896.	1897.	1898.	1899.	1900.	1901.
From gas plants	119,600	127,000	153,000	180,000	196,000	188,000	148,500
From blast furnace	14,600	16,500	18,000	17,700	18,000	18,000	16,000
From shale works	38,300	38,000	37,000	37,300	38,500	39,000	36,500
From coke ovens, producers, etc.	7,000	9,000	10,000	11,500	15,000	15,000	19,000
Total production	179,500	190,500	498,000	196,500	207,500	210,000	220,000
Consumption of United Kingdom	67,800	65,000	45,000	59,600	67,600	64,700	69,800

(*a*) *Zeitschrift fuer Angewandte Chemie*, April 23, 1901, and *Bradbury & Hirsch's Review* for 1901, p. 23.

The statistics of sodium nitrate importations show that the consumption of the United Kingdom is slightly increasing, being 121,000, 126,000, and 126,000 long tons for the years 1899, 1900 and 1901, respectively.

Production and Consumption of Ammonium Sulphate and Sodium Nitrate in Germany.—Germany absorbs nearly 40% of the sodium nitrate exported from Chile, and in addition to this about 44,407 gross tons of ammonium sulphate were imported from England in 1901. There are now about 5,750 by-product ovens in operation, which yield 115,000 metric tons of ammonium sulphate per annum. The consumption of ammonium sulphate in Germany has increased from about 80,000 metric tons in 1893 to about 175,000 metric tons in 1901, an increase of about 120%. This increased consumption of sulphate has not by any means reduced the importation of nitrate, which increased from 371,000 metric tons in 1893, to 530,000 tons in 1901, or over 40%. The explanation of the increased demand for nitrogen in excess of the home production is that the thorough educational campaign by Agricultural Institutions has awakened an appreciation of proper fertilization. Prof. König estimates that of the 484,543 metric tons of sodium nitrate imported in 1900, nearly 75% was used for fertilizing purposes.

[7] *Iron and Coal Trades Review*, March 14, 1902, p. 639.

The present nitrogen consumption for fertilizing purposes in Germany (exclusive of animal and vegetable refuse), is 350,000 metric tons sodium nitrate, 15·5%= 53,250 metric tons nitrogen, and 100,000 metric tons ammonium sulphate 20·0%=20,000 metric tons nitrogen, making a total of 73,250 metric tons of nitrogen.[8]

If all the German coke plants were equipped for the saving of by-products and all the ammonia were saved by the gas works, the following maximum ammonium sulphate production could be obtained at the present time:—

Coke Works.—Present production about 11,500,000 metric tons coke, which could yield annually, on the assumption of 75% coke and 1·15% sulphate results, 165,000 metric tons ammonium sulphate.

Gas Works.—Present production about 20,000 metric tons sulphate, which could be increased to 35,000 metric tons ammonium sulphate.

The maximum production could therefore not exceed 200,000 metric tons ammonium sulphate.

It is estimated that 40,000 metric tons of ammonium sulphate are required for miscellaneous purposes, which leaves 160,000 metric tons ammonium sulphate available for fertilizing purposes. The nitrogen equivalent of this last named quantity of ammonium sulphate is only 32,000 metric tons.

In other words, all the ammonia which could possibly be saved in the present state of the coke and gas industries would represent only 44% of Germany's present consumption of nitrogen in the form of sodium nitrate and ammonium sulphate for fertilizing purposes, and the wisdom of the German Government in acquiring sodium nitrate mines thus becomes evident.[9]

Production and Consumption of Ammonium Sulphate and Sodium Nitrate in the United States.—There are no exact figures obtainable, therefore only approximate estimates can be given. These however show the limited demand that exists here, especially when compared with Germany.

ESTIMATE OF AMMONIA SUPPLY AND CONSUMPTION OF THE UNITED STATES FOR 1901.

Supply.	Ammonium Sulphate Equivalent.	Consumption.	Ammonium Sulphate Equivalent.
Domestic production:	Short Tons.		Short Tons.
Gas works (crude and concentrated liquor)	12,000	Soda works (concentrated liquor)	6,000
Coke works (concentrated liquor and sulphate)	14,150	Refrigeration and ice manufactories (anhydrous and aqua ammonia)	8,000
Abattoirs, bone-carbonizing plants	2,000	Ammonium sulphate, fertilizers	16,000
Total production	*28,150*	Ammonium chloride	5,000
Imports for year ending June 30, 1901:		Ammonium carbonate, nitrate and picrate	1,500
Ammonium sulphate	14,486	Aqua ammonia for electroplating, miscellaneous, chemical and domestic purposes, balance	9,198
Ammonium chloride (muriate), (4,772,364 lb.)	2,959		
Ammonium carbonate (181,701 lb.)	98		
Total imports	*17,543*		
	45,693		45,693

The following table of the production of ammonium sulphate in by-product

[8] Prof. P. Wagner estimates Germany's entire nitrogen consumption for fertilizing purposes at 100,000 metric tons, which undoubtedly includes the organic fertilizers.

[9] *Zeitschrift fuer Angewandte Chemie*, March 18, 1902, and *Engineering and Mining Journal*, March 22, 1902.

coke ovens has been given in *L'Engrais*, 1901, which shows a variation in the figures for the United States from the preceding table, which is due probably to the assumption that the new coke ovens were in operation during 1901. Most of them, however, will not be completed until late in 1902 or early in 1903.

PRODUCTION OF AMMONIUM SULPHATE IN BY-PRODUCT COKE OVENS IN 1901.

United Kingdom	19,000 metric tons.
Germany	90,000 metric tons.
France	7,000 metric tons.
Belgium	8,000 metric tons.
Other European countries	10,000 metric tons.
United States	25,000 metric tons.

Ammonia from Gas Works in the United States.—The production of ammonia in gas works in the United States (equivalent to about 12,000 tons of ammonium sulphate per year) is increasing but very slightly owing to the extensive introduction of the water gas process, in which no ammonia is saved. Coal-gas works only are producing it, and practically all the larger works in this country are now equipped with ammonia stills.

The total amount of coal carbonized by gas works in the United States during 1901 is estimated at 2,100,000 short tons. In the large works with good practice, ammonia equivalent to 1·0% of sulphate is recovered, but in works of moderate size not more than from 0·6 to 0·8% sulphate equivalent is obtained. If an average yield of 0·8% be assumed, the possible maximum quantity of recoverable ammonia for 1901 would amount to 16,800 short tons sulphate equivalent. There were recovered 12,000 short tons during 1901, which leaves a waste of 4,800 short tons.

From these estimates it may be assumed that no increase in the manufacture of ammonia by gas works may be expected to an extent which could seriously influence the ammonia market.

Ammonium Sulphate from Coke Works in the United States.—The annual capacity of all the ovens now building and in operation may be estimated at 50,000 short tons of ammonium sulphate per year.

Ammonium Sulphate from Abattoirs and Bone Carbonizing Works in the United States.—A limited amount of second grade ammonium sulphate having about 19% nitrogen is produced in these works. Its price is from $2·50 to $3 less than gas liquor ammonium sulphate. The use of bone charcoal in sugar refineries is decreasing and no increase in the ammonia supply from these sources need be expected.

Imports of Ammonium Salts.—Since the introduction of by-product coke ovens the ammonium sulphate production has been nearly doubled. In the face of this the price has risen, and the imports, which were 16,822,090 lb. in 1890, were 28,971,761 lb. in 1901, an increase of 72%. This is due to its growing demand for refrigerating and fertilizing purposes, and the inadequacy of the domestic supply. The imports of ammonium chloride (muriate) and ammonium carbonate have been constantly decreasing as the domestic production can now supply the increase in demand. The imports of gas liquors, which were mostly from Canada, have ceased entirely. The tariff schedule has been responsible for some of the fluctuation in imports.

RATES OF DUTY ON AMMONIUM SALTS IMPORTS INTO THE UNITED STATES.

	McKinley Tariff. 1890.	Wilson Tariff. 1894.	Dingley Tariff. 1897.
Ammonium sulphate	0·5c. per lb.	20% ad valorem.	0·3c. per lb.
Ammonium chloride (muriate)	0·75c. per lb.	10% ad valorem.	0·75c. per lb.
Ammonium carbonate	1·75c. per lb.	20% ad valorem.	1·5c. per lb.

Prospects of Ammonia Supply.—From the foregoing it is plain that there is no prospect of any important increase in the ammonia from gas works and abattoirs, the only chance of increase in domestic supply being from by-product coke ovens. The extent to which this may be relied on may be estimated from the total quantity of coke produced in 1901, *viz.*, 20,533,348 short tons. If this were coked in by-product ovens about 27,500,000 short tons of coal would be required, which on an average yield of 1% would mean only 275,000 short tons of ammonium sulphate. To this may be added 25,000 tons from the gas works, making a total of 300,000 tons of ammonium sulphate, or 60,000 tons available nitrogen per year. Germany alone, with but two-thirds the population and smaller agricultural interests, uses 80,000 tons of nitrogen in the form of ammonium sulphate and sodium nitrate for fertilization, a quantity which exceeds by 20,000 tons the present possible capacity of the United States.

Ammonium Sulphate as a Fertilizer.—Plants remove from the soil certain elements which they assimilate and which are necessary for their growth. By continued removal of crops certain of these elements are exhausted, and unless they are replaced the richest soil will in time become exhausted. The three elements that are indispensable to plant growth, and without which even under favorable conditions and cultivation no satisfactory crop can be obtained are nitrogen, potassium and phosphorus. All commercial fertilizers derive their value from the proportion of these substances contained in available form. Nitrogen is by far the most important and the most expensive. The value of ammonium sulphate as a source of nitrogen is admitted, and the increased crop returns, after the cost of the fertilizer has been deducted, is a matter which has been conclusively demonstrated. In order to encourage agricultural progress in general and with this the proper use of fertilizers the United States Government has established agricultural experiment stations throughout the country, particularly in the East and South, where the land has already shown signs of depletion. The outcome of this intelligent propaganda will inevitably increase the demand for ammonium sulphate enormously. For a detailed discussion of the fertilizing action of ammonium sulphate recourse must be had to the literature of the subject.

Other By-Products.—There are, outside of tar and ammonia, other by-products saved in the coking operation (benzole and its homologues, cyanides, sulphur, etc.).

The points brought out in the preceding discussion may be briefly summarized as follows:—

1. The by-product coke oven industry is firmly established in the United States. A great number of ovens are now in operation and in course of construction, representing many millions of dollars of investment.

2. The coke has proved at least equal to the best bee-hive coke.

3. New coal fields have been opened for the manufacture of metallurgical fuel by means of the by-product coke oven.

4. Several plants have been erected by The United Coke & Gas Co. and others, which demonstrate on an extensive scale the feasibility of manufacturing a smokeless fuel for domestic purposes, etc., simultaneously with large quantities of an illuminating gas of high candle-power. These results open a large field for the erection of coke plants outside of the manufacture of metallurgical coke.

5. The production of tar and ammonia in the United States is very small and the consumption per capita falls far behind that of other countries, so that we may expect a ready disposal at remunerative prices of all by-products which can be saved. Since the introduction of by-product coke ovens the prices of tar and ammonia have increased instead of decreasing and the importations of ammonia have also increased.

6. The present tar production of the United States is disposed of mostly for industries which are less extensively developed in European countries (roofing paper and paving pitch). On the other hand, the tar consuming industries of Europe are hardly known in this country (briquette manufacture, chemical industries, etc.).

7. Even if all of the ammonia from coal carbonized now in the United States could be saved it would not be sufficient to meet the nitrogen requirements for fertilizing purposes. At present Germany consumes more nitrogen in the form of ammonium sulphate and sodium nitrate than is represented by all the ammonium sulphate which the United States could save.

Progress in Power Plants Using Gas Producers and Gas Engines.

By William Kent.

In the article "Fuel and its Economical Utilization," which I contributed to The Mineral Industry, Vol. VIII., mention was made of the recent use of gas engines as blowing engines for blast furnaces in European iron works, and of the use in gas engines of producer gas derived from the Dawson and Wilson producers in England, the Lencauchez producer in France and the Taylor producer in the United States. One of the former limitations to the general use of gas engines supplied by producer gas was that the producers designed to make gas for gas engines were almost exclusively restricted to comparatively expensive anthracite coal or coke. In 1897, however, Brunner, Mond & Co., at Norwich, England, erected a producer which operated successfully with soft coal slack. In conclusion the article stated that the prospect of the displacement of the steam engine by the gas engine was very unpromising, and a summary of the special field of the gas engine was given as follows:—

"The internal combustion engine finds its field in special locations and conditions, such as automobile carriages, small yachts and torpedo boats, small powers (1 to 50 H.P.) where the use of a steam boiler entails more trouble than a gasoline motor and in places where water is scarce or bad. The field of the gas engine will be greatly increased if fuel gas can be distributed cheaply, as may be the case when by-product coke ovens have been generally introduced; under this condition the gas engine may become a serious competitor of the steam engines in sizes up to 500 H.P. It is doubtful, however, if a large electric lighting and power plant of 10,000 H.P. can ever be built to run with gas engines as cheaply as with steam engines, with the modern appurtenances of coal handling machinery, mechanical stokers, economizers and superheated steam. One horse power per hour from one pound of Pocahontas coal is already within the possibilities of steam engine practice, a figure very close to the best gas engine records from anthracite coal gas. With the fuel consumption of steam engines reduced to this figure the only hope for a gas engine to become a serious competitor is that gas from retort ovens may be sold at a price below its fuel value—the expense of running the coke oven being paid by the coke and the valuable chemicals which are obtained from the tarry by-products and the ammoniacal liquor. Until this happens the steam engine will continue to be the machine for utilizing the greater part of the coal that is used for power purposes."

Shortly after the publication of The Mineral Industry, Vol. VIII., the Westinghouse Machine Co. and the Westinghouse Electric & Manufacturing Co. issued a pamphlet which gave an entirely different view of the prospects of the gas engine operated by producer gas. It was claimed that the three conditions essential to the general application of gas as a fuel for engine driving had been realized, namely, its generation, its distribution and its use, and that this being the case, the resultant development of power by gas engines would revolutionize the present situation; the gas engine would supplant the steam engine as the latter would then be too costly to maintain; the steam boiler would be used for heating purposes only, the steam being generated over gas furnaces; coal would be

supplanted by gas for cooking and heating; gas lighting in cities and towns would be supplanted by electric lighting from generators driven by gas engines, and power, street and elevated railways would also be supplied by generators driven by gas engines. The following is quoted from the pamphlet referred to above:—

"The existing demand for large electric power units for operating street railways has resulted in the installations of plants of the following general outline:

"A large central steam power and electric generating plant, the electric generators being of the multi-phase type for the generation of currents at high voltages; a high tension system of distribution to local stations, where there are step-down transformers, which supply alternating currents to rotary converters, which in turn feed direct currents to third rail or other circuits, for the operation of the motors on the cars.

"Coal can be made into gas of a satisfactory quality at gas works suitably located. The gas can be taken by pipes to gas engines placed in the positions corresponding to the sites of the rotary converters of the foregoing plan, for a capital expenditure below that required for an equivalent steam boiler and engine plant. The cost for fuel per electrical horse-power so delivered should not exceed 50% of the cost of the fuel for generating electricity by steam for similar service. At the present time projects for the electric equipment of underground, elevated and surface railways are everywhere discussed. The use of gas engines for developing the electrical energy, with suitable pipes laid for conducting the gas, would make the cheapest and most reliable system to construct and operate. It should be quite within the scope of the operations of existing gas companies to erect special gas works, put down special pipes, and supply gas for the operation of large unit gas engines in connection with such lines. The gas companies could avail themselves of the most recent processes for the generation of gas, many of which are well developed and understood."

On January 9, 1900, Mr. Westinghouse wrote a letter to the New York *Times* advocating the combination of the electric light and power companies in New York City, viz.: the Metropolitan, Third Avenue, and Manhattan Elevated Railways, the New York Gas and Electric Light, Heat & Power Co., and the United Electric & Power Co., with a view to unite in a common plan to provide the electricity needed in their operations. Mr. Westinghouse also mentioned the possibility of manufacturing fuel gas from garbage and soft coal which could be utilized to drive gas engines with electric generators, in this way excluding thousands of steam engines and boilers, which make a very considerable demand upon the water supply of the city. The gas engine control stations could be so located that the water needed for engine-cooling purposes would be derived from the river.

The above-mentioned pamphlet of the Westinghouse Co. and the letter were widely quoted in technical journals at the time, yet after the lapse of two years the huge electrical enterprises quoted by Mr. Westinghouse have installed steam boilers and engines, and in addition the New York Rapid Transit Underground Railway and the Underground Railways of London have contracted for a steam equipment. The Westinghouse Machine Co. has greatly enlarged its plant for the building of large steam engines and has further shown confidence in the future of steam by going to considerable expense in preparing to build the Westinghouse-

Parsons steam turbine. The company, however, has continued the development of the gas engine, and in April, 1902, it erected its first 1,000-H.P. gas engine for test in the same building in which it is constructing several 10,000-H.P. steam engines.

Taking up the discussion of the points set forth in the pamphlet of the Westinghouse Co., while it is true that the generation, distribution and use are the three conditions essential to the general application of the producer gas for gas engines, but little progress has been made along this line. The producer has been introduced to a limited extent but is still an expensive apparatus, costly to maintain and to operate. The distribution of gas in pipes is successfully accomplished in the transport of natural gas which has a heating value of 1,000 B.T.U. per cu. ft., and of illuminating gas, heating value of 640 B.T.U. per cu. ft., but it is an entirely different matter to distribute producer gas of only 125 B.T.U. per cu. ft., which to transport to a great distance would involve a high cost for piping.

As a thermo-dynamic machine the gas engine is far superior to the steam engine, as it turns from 50 to 100% more of the heat energy developed in its cylinders into mechanical work. To offset this advantage the gas engine is more bulky and costly than a steam engine of equal power and is more expensive to maintain. No gas engines larger than 1,000 H.P. have as yet been built in this country, while steam engines of 10,000 H.P. are becoming quite common. Furthermore the steam engine is being rapidly improved by the use of high pressure, high speed, poppet valves and superheated steam. Steam turbines of the de Laval and Parsons types are rapidly being introduced, both in the United States and abroad. A large contract for steam turbines has been given by the underground railways of London, but no large contracts for gas engines have been placed up to the present time.

The Otto Gas Engine Works[1] state that there is nothing new in gas engine practice worthy of special mention. This company has made no radical changes for some time, but has confined its attention to the perfection of minor details to bring the grade of the engine up to a high standard. As an example of the use of the Taylor anthracite gas producer with its engine is quoted the installation at the Erie railroad shops in Jersey City, N. J.

Westinghouse, Church, Kerr & Co.[2] state that while a number of their gas engines are successfully operating on producer gas, detailed efficiency tests have not been made. The general results obtained, however, indicate that the performance is very satisfactory and corresponds to a consumption at full load of not more than 1·25 lb. coal per brake H.P. per hour. The gas engine of this company develops a brake H.P. with from 10,000 to 12,000 B.T.U. per hour, and the producer builders generally guarantee to evolve from 75 to 80 cu. ft. of gas per lb. of coal, the gas having a calorific value of not less than 125 B.T.U.

R. D. Wood & Co., of Philadelphia,[3] builders of the Taylor gas producer, state that the economy of the gas engine and producer plant at the Erie railroad in Jersey City has been very satisfactory, although no test figures have as yet been

[1] Private communication, Jan. 18, 1902. [2] Private communication, Jan. 23, 1902.
[3] Private communication, Jan. 21, 1902.

published. If the efficiency of the boiler be assumed to equal that of a producer (which as a rule is unfair to the producer) the thermal efficiency of the gas engine will be superior to the steam engine. Most engine builders guarantee 1·25 lb. coal per brake H.P. per hour, and one builder gives as low as 1 lb. coal per brake H.P. per hour. It is perfectly safe to guarantee 1·25 lb. coal per brake H.P. per hour, and the Westinghouse engine has made it on 1·17 lb. coal, including the steam for the producer. It is a question whether the steam engine can compare with this except under test conditions. While the gas engines and producer plants may exceed the cost of an equivalent steam plant, the economy of the former will readily offset the excess cost of 25% per year. The labor involved in running a gas plant will certainly not exceed that of an equivalent steam plant, and may be 75% of it or less. The repairs to a steam plant are not excessive, but it is reported that the equipment of the Erie railroad plant has involved a repair cost of less than $100 for nearly three years. Inferior fuel may be used in the producer, but with good stoking there is less in this advantage than formerly except for special fuels.

Progress in Construction and Operation of Gas Producers.

The Loomis-Pettibone Gas Producer.—The Loomis-Pettibone Co., of New York, has made considerable progress in the introduction of a producer which makes gas from soft coal or wood. In construction it is of the double type, making alternately producer gas and water gas. These gases may be mixed in a gasometer for future use in gas engines. The following description and illustration are of a modern producer of this type. Figs. 1 and 2 showing the cross-section and plan of the Loomis-Pettibone gas producer and boiler, the two generators *A* and *B*, the vertical boiler *C*, the water-cooled valves *D* and *E*, the producer-valve *F*, the water-gas valve *G*. The generator is cylindrical in form and is constructed of iron and steel, the general dimensions being from 3 to 11 ft. in diameter and from 12 to 18 ft. in height. The lining is of fire brick, with fire brick arched grates, ash pit and boiler flue in the bottom. There is a door on top for charging and for the admission of air, also two cleaning doors above the grate and one below the grate, opening into the ash pit. In starting fires in the generators a layer of coke or coal about 5 ft. in depth is put in and ignited at the top, the exhauster creating a downward draft. When the body of fuel is ignited, coal is frequently charged, raising the fuel-bed to about 8 ft. above the grates, at which height it is maintained. Bituminous coal is generally used, being charged at intervals as needed, through the feed-door in the top of the generator. Air also is admitted through the same doors and is drawn down through the fresh charge of coal and then through the hot fuel-bed beneath by the exhauster. The resultant producer or generator gas is drawn down through the grates and ash pits of generators *A* and *B*, valves *D* and *E*, up through the vertical boiler *C*, valve *F* to scrubber and exhauster (valve *G* being closed), and is delivered into a small gas holder for supply to the furnaces. When the exhauster has brought the fuel up to incandescence the charging doors *H* and *I* are closed, valve *E* lowered, valve *F* closed, and valve *G*, leading to the water-gas holder, opened. Steam is then turned on into the ash-pit of generator *B*, and, in passing through the incandescent coal, is

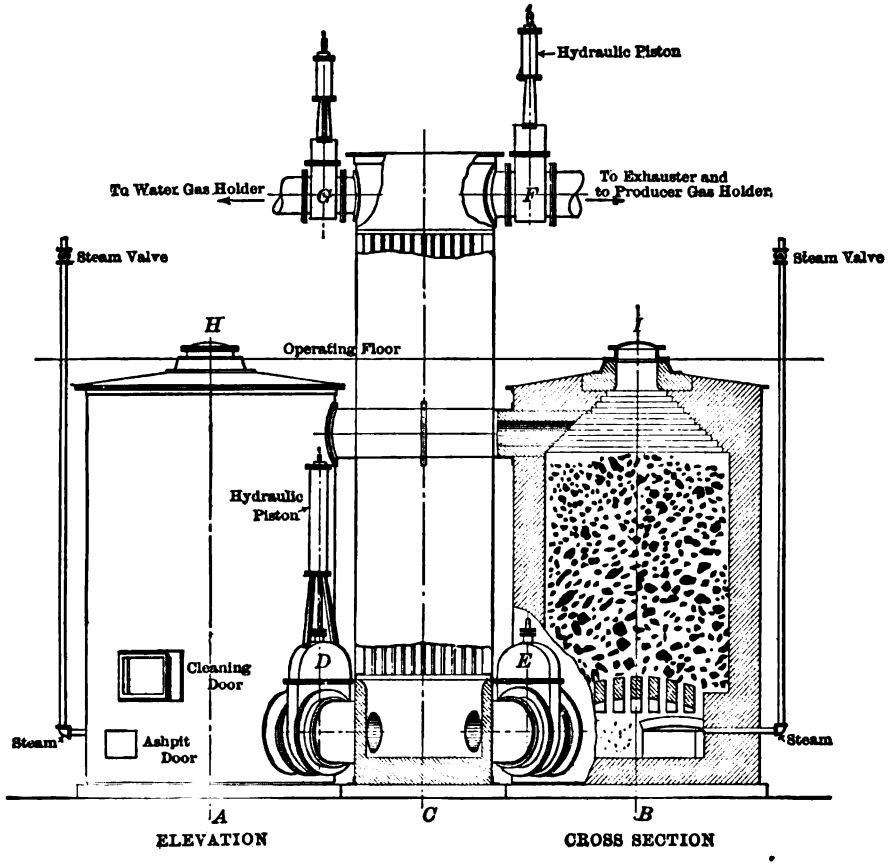


FIG. 1. THE LOOMIS-PETTIBONE GAS PRODUCER AND BOILER.

decomposed, forming water gas. From generator *B* the gas passes through the connecting-pipe shown near the top of the generators, and down through the generator *A*. The gas passes through valve *D* into and up through the boiler *C*, and thence, after being washed in the scrubber, is conducted into a holder. Water gas is made for five minutes, when, the temperature of the fuel-bed having been considerably reduced, the steam is shut off, valve *G* closed, valves *F* and *E* opened, and the charging doors *H* and *I* opened. This process of making water and producer gas is alternated at intervals of five minutes or more, according to the quality of gas desired. In making the next run of water gas the course of the steam is reversed: *i.e.*, valve *D* is closed and the steam is turned into the ash-pit of generator *A*. Valve *E* is left open, but the other valves, *F* and *G*, and the charging doors, *H* and *I*, are operated the same as in the first case. The operation of a pair of generators of this type is exceedingly simple. A man with ordinary intelligence, even if he has had no previous experience in the manufacture of gas, would be competent with a week's practice to take charge and run the apparatus. As the valves are provided with hydraulic pistons, the labor is reduced to a minimum and only a few seconds are required to change from making one kind of gas to another. While the fires are being blasted and during the making of a run of water gas, the hot gases in passing through the boiler give up a large proportion of their sensible heat, which is converted into steam. This, in turn, is directed under the fires in the generators for decomposition. Another advantage of the double generator apparatus is that, as all gas is made to pass through the fire, the tarry matter from the coal is converted into fixed gases that can be conducted any distance through ordinary pipe and at any temperature or pressure. Again, as the steam is forced through two fires, the percentage of condensable water vapor is exceedingly small. The gas after passing down through the hot fuel-bed is free from tar and may readily be conveyed through pipes to any distance required.

Instead of making water gas in every alternate stage for the same length of time as producer gas, the generator may be worked on producer gas alone, steam being then admitted at various points while the exhauster is running and the operation of making producer gas is going on. It is, therefore, not requisite to alternate the action of the generators so frequently as every four or six minutes; but only so much water gas need be made as may be called for by the requirements of the work to which the process is applied. From the generating plant the producer gas is delivered to one holder and the water gas to another holder. From these holders the two gases pass to an especially designed proportional mixing valve, by means of which they are uniformly mixed in any proportion desired. From this mixing valve the mixed or power gas passes to the engines wherever located. The gas is fixed, clean, and free from tar and all impurities, can be conveyed in pipes to any distance, and will not foul the engine. The gas is also well suited to a large variety of industrial work in direct fired, semi-regenerative and regenerative furnaces.

The Plant of the Moctezuma Copper Co., at Nacosari, Mexico.—The plant of the Moctezuma Copper Co., owned by Phelps, Dodge & Co., of New York, was described by Mr. James Douglas at the meeting of the American Institute of

Mining Engineers in the City of Mexico in 1901. The special advantage of a gas plant in this district is on account of the absence of good fuel. The Loomis down current gas producer was modified so that both water gas and producer gas were made together by introducing steam into the producer continuously, which yielded a continuous production of mixed gas. When the fuel became too highly incandescent steam was introduced. The cost of wood at Nacosari is $3, as compared with $25 per ton of coal, and in many cases the wood gas produced was of better quality than the gas from coal. Typical analyses showed: Wood gas, 14% CO, 20% H, 16% CO_2 and 47·7% N; coal gas, 20% CO, 14% H, 8·2% CO_2 and 55% N. The power plant is described elsewhere in this volume under the section devoted to the review of copper mining in Mexico.

The Plant of the Winchester Repeating Arms Co., at New Haven, Conn.—The Loomis-Pettibone producer in use at this plant is at present being increased to double its former size. There are two gas mains about the works, one to convey the water gas and the other the producer gas. The water gas is used for drop forging, welding, brazing, annealing, tempering and for smelting fires. The mixed gases are used for annealing brass in large muffles and rotary annealing furnaces, lead melting furnaces and for direct fired furnaces. The mixed gases are also used for power purposes with gas engines. At present three gas engines are in operation, one of 95 H.P., one of 80 H.P., and one of 30 H.P. size. Three additional 165-H.P. Westinghouse gas engines are being installed for direct connection to electric generators. The current is used for power purposes having direct current motors located about the works.

The Plant of the Detroit Mining Co., at Morenci, Arizona.—This plant is similar to the one at Nacosari, and is located on the railroad between the smelter and concentrator. Gas is piped one mile to the smelters supplying two 200-H.P. three-cylinder vertical Westinghouse gas engines, each belted to a 120-K.W. alternating current dynamo. The dynamos operate in parallel and supply current to the motors and for lighting. A 60-H.P. Stockport gas engine operates the conveyors and briquetting machine, and a 60-H.P. Fairbanks & Morse gas engine runs an air compressor. The gas is piped 2,000 ft. to the concentrating mill, operating three 80-H.P. Otto-Crossley engines belted to a counter shaft which drives the two-unit mill. An addition of 800 H.P. of gas engines is being made to this plant.

The Plant at Minas Teclotes y Anexas, Santa Barbara, Mexico.—A 500-H.P. plant with four 140-H.P. Otto gas engines is being installed at these mines, which are operated by the Guggenheim Exploration Co.

From this information, furnished by the Loomis-Pettibone Co., it appears that the field for its producer in connection with gas engines has thus far been limited either to locations where coal is very expensive, as in Arizona and Mexico, or to places in which the gas can be conveniently used for other purposes as well as for gas engines, as in the case of the Winchester Repeating Arms Co., New Haven, Conn., where it is used for heating, welding, brazing, etc. The soft coal producer has not yet been introduced for running gas engines alone in any part of the United States where coal is moderately cheap, and there appears to be no prospect of its soon supplanting the steam boiler and engine in any large power plant.

The Mond producer seems to be making some progress in England, but only in connection with works for the production of chemical products from the distillation of coal. A company has been organized with $5,000,000 capital to supply fuel gas to a district west of Birmingham, England, but it bases its expectation of profit on the market for ammonium sulphate, the gas being considered a by-product. The gas blowing engine, using the waste gas from blast furnaces, is making considerable progress in Europe but it has not yet been introduced in this country.

COPPER.

THE production of copper during 1901 amounted to 597,443,212 lb., against 600,832,505 lb. in 1900, a decrease of but 3,389,293 lb. during the year, which was largely due to the efforts of the Amalgamated Copper Co. to corner the copper market. The output of its Montana mines was restricted, and certain Michigan mines were induced to co-operate with it to control the American copper market and to maintain the price of copper at 17c. These efforts resulted in disaster to the Amalgamated interests, for at the close of the year the market fell heavily, and the allied interests were left with large stocks of copper on hand. The output of copper for Montana during 1901 was 229,870,415 lb., against 254,460,713 lb. during 1900, a decrease of 24,590,298 lb. for the year, thus recording a production which was less than that of 1899. Michigan reported a considerable increase over 1900, with 155,511,513 lb., as compared with 144,227,340 lb. during 1900. In spite of an expected decline in the production of Arizona during 1901 that Territory increased its 1900 production by over 10,000,000 lb. Among the other States, Utah and California scored notable advances, while Colorado's 1901 production was very slightly more than that of 1900.

According to reports of American copper refiners, the amount of copper refined by electrolytic methods was approximately 80% of the total of 1901. The production of copper sulphate was 78,004,257 lb., compared with 78,218,478 lb. in 1900, while the average price for 1901 was 4·1c. per lb., as compared with 4·99c. for the previous year. Of the total production of copper sulphate in 1901 the amount recovered as a by-product was 51,000,000 pounds.

The stock of copper on hand at the end of 1901 was 209,587,698 lb., as against 93,050,230 lb. at the end of 1900.

The imports of copper during 1901, as reported by the smelting and refining companies and the United States Treasury Department were 176,472,369 lb., against 103,805,793 lb. in 1900, while the exports amounted to 227,194,184 lb., as against 352,731,143 lb. in 1900, showing a considerable decline. Foreign purchasers of copper adopted a hand to mouth policy, with a result that exports declined, and toward the close of the year the price of Lake copper fell so rapidly that the average for the year was but 16·55c. per lb., while the average for the first

nine months was 16·77c., against an average for 1900 of 16·52c. for Lake copper, and 16·11c. for electrolytic.

COPPER PRODUCTION IN THE UNITED STATES. (LB. OF FINE COPPER.)

States.	1898.		1899.		1900.		1901.	
	Pounds.	Long Tons.	Pounds.	Long Tons.	Pounds.	Long Tons.	Pounds.	Long Tons.
Arizona	110,823,864	49,475	125,377,758	55,972	115,403,846	51,520	126,183,744	56,332
California	21,543,229	9,618	23,915,486	10,677	29,639,987	13,232	33,667,456	15,030
Colorado	10,870,969	4,853	10,614,252	4,739	7,826,949	3,494	7,872,529	3,515
Michigan	156,669,098	69,951	155,845,786	69,574	144,227,340	64,387	155,511,513	69,425
Montana	216,979,334	96,866	237,958,951	106,229	254,460,713	113,599	229,870,415	102,621
Utah	5,385,246	2,404	9,310,344	4,156	18,504,726	8,261	20,116,979	8,981
Eastern and Southern States	4,478,218	1,999	3,804,617	1,698	6,918,122	3,088	6,860,039	3,063
All others	2,134,999	953	4,983,000	2,227	12,536,850	5,597	17,360,537	7,750
Copper in sulphate (*b*)	7,015,375	3,132	9,507,897	4,245	11,313,962	5,051	11,730,000	5,232
Total domestic production	535,900,232	239,241	581,319,091	259,517	600,832,505	268,229	609,173,212	271,949
Stock January 1	48,882,143	21,821	54,361,470	24,269	88,722,559	39,608	93,050,230	41,541
Imports bars, ingots, old, and ores	43,479,288	19,410	94,568,050	42,218	103,805,793	46,342	176,472,369	78,782
Total supply	628,261,663	280,474	730,248,611	326,004	793,360,857	354,179	878,695,811	392,275
Deduct exports	299,765,054	c133,824	249,928,941	c 111,573	352,731,148	157,469	227,194,184	101,426
Deduct consumption	274,135,139	122,382	391,602,111	174,822	347,579,484	155,169	440,913,929	196,887
Stock December 31	54,361,470	24,269	88,722,559	39,608	93,050,230	41,541	209,587,698	93,566

(*a*) This includes copper imported in low-grade Spanish and other pyrites chiefly for sulphur, and the copper imported from Canada in copper-nickel matte, in which the nickel is the metal of chief value; also the copper in certain gold and silver ores. These items did not until 1898 appear in the United States statistics of imports. (*b*) Including only the copper in sulphate obtained as a by-product in 1898. (*c*) Not including Mexican copper en route for Europe.

Alaska.—During 1901, the Pacific Coast Copper Co., capitalized at $5,000,000, purchased from the Pacific Coast Mining, Milling, and Development Co., of California, 10 copper claims, of which five are on Copper Mountain and five near Summit Lake, Prince of Wales Island. Development work was begun during the latter part of the year. The mines are accessible to the coast and steamship transportation, and the ores consisting chiefly of chalcopyrite in iron ore, carry small values in gold and silver. The property of the Alaska Copper Co., comprising 18 claims, a tramway one mile long to the wharf at the harbor, saw-mill, buildings, etc., was sold to Spokane, Wash., parties during the latter part of the year. The ore consists of malachite and chrysocolla in a quartz gangue carrying as high as 30% Cu besides values in gold and silver. It is said that the ores can be concentrated into an 85% matte at one smelting at a cost of $3 per ton. Prince of Wales Island is 140 miles long by 40 miles wide, and apparently the copper ores are generally distributed over it.

Arizona.—(By James Douglas.)—Despite an increase in production of copper of 10,779,898 lb., Arizona made less progress during 1901 than was expected. The Arizona Copper Co. closed its plant for six weeks during the reconstruction of its smelting works; the United Verde Co. reduced production in order to re-equip its principal shaft, and the serious drought in the southern portion of the Territory interfered with the operation of other producers. The conditions for the year 1902 afford promise of a somewhat increased output. The works of the United Verde Co. are equipped for active operations, and the Arizona Copper Co. is capable, with its new smelter, of making at least 26,000,000 lb. a year. The Copper Queen works were enlarged during the year, but it was not deemed advisable to urge them to their fullest capacity. The Old Dominion mine and

furnaces were in active operation during 1901 and although sulphides have been met with in the lower levels they were not in sufficient quantity to induce the management to make their mixed oxidized and unaltered ores into matte for concentration in the converter. The Old Dominion therefore is still the only concern which makes copper bars in quantity direct from the ore. The United Globe mines, and others in the vicinity of Globe, have been shipping a very moderate quantity. The Black Warrior Co. has erected an acid chamber and leaching plant, and has already commenced the extraction of copper on a working scale by sulphuric acid from the very siliceous ores of its mines. The result of its operations may have a notable influence on the method of treatment of copper ores in the Southwest, where there are large bodies of low siliceous oxidized ores.

Of the new companies the Calumet & Arizona Co. is building works at Douglas, in the Sulphur Spring Valley, to treat the ore which it has opened up in the Irish Mag mine, near Bisbee, and the Shannon Co. is erecting a 500-ton concentrator and smelting works of adequate capacity to treat the ores of the Metcalf and adjacent claims in the Clifton district. The Black Diamond Co. and other new producers may add somewhat to the total yield of the territory. The Copper Queen Co. is designing new works to be erected at Douglas, where ample space is available and abundant water flows at a shallow depth below the surface. With the exception of the Shannon Co. none of the new concerns is likely to produce during 1902. While there are no signs in any of the mines of Arizona to indicate exhaustion, none of the companies seems to be imbued with the ambition to force production and make high records. Arizona's output, therefore, in the future may be expected to show a moderate increase, but the policy of all the companies interested seems to be to keep production within the bounds of consumption, and not to allow ambition or rivalry to influence their conservative policy.

COPPER PRODUCTION IN ARIZONA. (*a*) (POUNDS OF FINE COPPER.)

Mines.	1896.	1897.	1898.	1899.	1900.	1901.
Arizona Cop. Co..	13,042,000	13,727,911	18,169,096	19,072,709	19,697,086	20,535,800
Copper Queen...	23,298,150	23,999,873	33,749,390	36,901,684	34,382,309	39,781,338
Commercial.....	46,040	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*
Detroit.....	7,016,348	8,405,138	11,428,992	13,906,253	10,749,258	17,535,000
Old Dominion....	5,650,000	2,000,000	1,800,000	6,300,000	7,155,000	10,094,300
United Verde....	22,327,950	31,355,025	42,328,926	43,995,932	39,970,193	34,520,695
United Globe....	2,020,565	1,241,975	2,847,460	4,451,180	*Nil.*	880,100
Other mines.....	344,268	290,000	*e* 500,000	*e* 750,000	*e* 3,450,000	*e* 2,886,516
Totals.....	73,745,321	81,019,922	110,823,864	125,377,758	115,403,846	126,183,744

(*a*) Reported by producers direct to THE MINERAL INDUSTRY. (*e*) Estimated.

California.—The copper mining industry made good progress in 1901 as regards output and new developments and the outlook for the future appears encouraging. In Shasta County, which is the principal center of the copper industry, a large amount of prospecting and exploration work was done, and activity in this direction was also noticeable in other parts of the State, more particularly in Amador, Calaveras, Madera, Fresno, Mariposa, and San Bernardino counties. The Mountain Copper Co., Ltd., at Keswick, the largest producer in California, increased its output of matte and refined copper, although the ore tonnage from

its mines was considerably below that of the preceding year. The output of the Keswick smelter was 13,271 tons, this amount representing metallic copper in matte. From the year's operations a total profit of £380,144 was derived, out of which the sum of £250,000 was set aside for the reserve and depreciation fund, £125,000 paid in dividends, and £5,144 added to the surplus account. Especial attention was directed by the management to the location of new ore bodies and two discoveries were made that are now being explored. At the annual meeting of the stockholders in London a plan was proposed for the distribution of the accumulated surplus among the stockholders; the scheme as outlined involved the issuance of new shares to the amount of £250,000 and also the creation of debenture stock amounting to £750,000 and bearing interest at 6%. The latter is to be distributed among the stockholders and will be subject to future redemption out of the earnings and assets which may not be required for the company's operations. The De La Mar properties in Shasta County were transferred to the Bully Hill Smelting & Refining Co., a corporation organized under the laws of New Jersey. The output of the Bully Hill smelter during the latter part of the year, according to report, was about 350 tons of matte per month. According to reports by the State Mineralogist, the amount of copper produced during 1901 was 34,931,985 pounds.

Colorado.—The production in 1901 as reported by Hon. Harry A. Lee, Commissioner of Mines, was 7,872,529 lb., against 7,826,949 in 1900. More than one-half of the former total was contributed by San Juan and Lake counties. No new developments of importance were recorded except the construction of a smelter at Salida, in Chaffee County, which will have two furnaces for treating pyritic ores. The development of pyritic smelting in this State will be found in the article "Progress in Pyritic Smelting during 1901," elsewhere in this volume.

Idaho.—Favorable progress was made in the Seven Devils district, but as in previous years, the operations were limited mostly to construction and development work. It is expected that the railroad to Cuprum will be opened for traffic before the end of the present year, when the mines will commence to produce on a larger scale. The Boston & Seven Devils Copper Co. started construction on a 100-ton smelter at Weiser which, when completed, will treat the ores from the company's mines.

Maryland.—The Mt. Washington Copper Co., of Mt. Washington, shipped several carloads of ore during the year, to Newark, N. J., for refining. The ores are bornite and chalcopyrite, and contain small values in gold and silver. Considerable development work was accomplished, the old stopes and levels, abandoned since 1866, were cleared out and a new straight shaft started.

Michigan.—The output in 1901 was 155,511,513 lb., the largest recorded in the history of the State. The extension of operations by some of the more important producers, including the Calumet & Hecla, Quincy, and Osceola, was mainly responsible for the increase, although the contributions from the smaller properties and from the mines under development were notably larger than in preceding years. While the recent decline in copper prices doubtless will have an adverse influence upon the production of the new mines, all of the prominent companies, owing to their foresight in applying a portion of the increased profits

during the last three years to developments and improvements, are in position to materially lessen the cost of producing copper. It may be assumed, therefore, that operations will be continued by these companies on about the usual scale.

COPPER PRODUCTION IN MICHIGAN. (POUNDS OF FINE COPPER.)

Mines.	1896.	1897.	1898.	1899.	1900.	1901.
Arcadian	*Nil.*	*Nil.*	*Nil.*	500,000	*e* 800,000	*e* 1,000,000
Atlantic	4,894,228	5,109,663	4,377,399	4,675,882	4,930,149	4,666,889
Baltic	*Nil.*	*Nil.*	42,766	603,570	1,735,060	2,641,432
Calumet & Hecla	90,356,733	88,378,986	94,103,000	98,002,137	81,403,041	82,519,676
Central	469,243	611,172	291,339	*Nil.*	*Nil.*	*Nil.*
Franklin	2,746,076	2,908,384	3,568,978	1,230,000	3,663,710	3,757,419
Isle Royale	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*	2,176,000
Kearsarge	1,337,226	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)
Mass	38,684	24,081	*Nil.*	61,000	*Nil.*	*e* 800,000
National	53,762	28,959	18,441	*Nil.*	*Nil.*	*Nil.*
Osceola Consol'd	6,251,304	9,500,000	11,800,000	10,950,000	11,200,000	13,723,571
Quincy	16,863,477	16,924,618	16,354,061	14,301,182	14,116,551	20,540,720
Ridge	*Nil.*	12,590	.....	(*b*)	(*b*)	(*b*)
Tamarack	16,495,000	20,000,000	22,500,000	17,750,000	18,400,000	18,000,852
Tamarack Junior	2,330,000	(*a*)	(*a*)	(*a*)	(*a*)	(*a*)
Wolverine	2,195,791	2,316,296	4,588,114	4,789,015	4,778,829	4,946,126
All other mines	27,000	25,000	*e* 25,000	2,983,000	3,200,000	738,828
Totals	144,058,524	145,839,749	156,669,098	155,845,786	144,227,340	155,511,513

(*a*) Consolidated with the Osceola. (*b*) Consolidated with Mass. (*e*) Estimated.

The subjoined tables show the results obtained by the principal mines, their capitalization, profits and itemized costs of production for the period 1897-1901. Similar information covering preceding years will be found in THE MINERAL INDUSTRY, Vols. I. and IX.

The Calumet & Hecla Mining Co. continued the extensive improvements to its milling and smelting plants which have been under way for some time, bringing them near to completion at the end of the year. The new six-stamp mill designed for treating ore from the Osceola amygdaloid will have a capacity of about 3,000 tons per day, or 1,800 tons per day when working on the conglomerate ore. Wilfley tables are to be installed for concentrating the slimes, and a tailings wheel 65 ft. in diameter and weighing over 500 tons will dispose of the waste material. The smelting works at Lake Linden were also partially reconstructed by the building of six new reverberatories to take the place of a like number of old furnaces. The new furnaces are supplied with platforms on which the ore is dried before being charged. The Osceola Consolidated Mining Co. did a large amount of development work in its mines, especially in the Osceola branch, where some very productive ground has been found, and in the North Kearsarge, which

CALUMET & HECLA MINING CO.

Year.	Capital Paid In.	Real Estate. Amount Invested.	Personal Estate. Amount Invested.	Debts.	Credits.	Copper Produced Lbs.	Yield. (*b*) %	Average Price per lb. (*a*)	Estimated Receipts.	Dividends.
1892	$1,200,000	$5,718,369	$5,255,080	$1,252,956	$4,045,277	58,292,576	3·40	11·67c.	$6,802,744	$2,000,000
1893	1,200,000	6,096,484	5,781,900	689,572	4,185,729	62,825,674	.....	10·91	6,854,281	2,000,000
1894	1,200,000	6,354,690	6,054,216	812,124	5,464,671	61,842,722	.....	9·63	5,955,454	1,500,000
1895	1,200,000	7,000,578	6,200,397	1,295,377	7,204,231	77,439,907	.....	10·66	8,254,494	2,000,000
1896	1,200,000	7,169,786	6,392,063	1,301,215	8,866,542	90,356,733	3·09	10·96	9,921,169	2,500,000
1897	1,200,000	13,596,348	6,265,426	1,275,599	3,668,150	88,378,986	.....	11·12	9,827,743	5,000,000
1898	1,200,000	14,223,895	4,134,321	2,235,543	6,280,589	94,103,000	3·07	12·01	11,301,770	5,000,000
1899	1,200,000	14,082,991	7,215,716	2,298,467	1,669,622	98,002,137	.....	16·92	15,788,162	10,000,000
1900	1,200,000	16,545,511	3,092,768	.....	1,676,766	81,403,041	.....	.....	.....	7,000,000

(*a*) Prices obtained by taking the average prices realized by the other leading mines, including Quincy, Tamarack, Atlantic and Wolverine. (*b*) Computed from the shipments of freight over the Hecla and Torch Lake Railroad. On this basis the yield in 1891 was 3·13% and in 1875, 4·30%.

ATLANTIC MINE.

Year.	Capital.	Stamped.	Fine Copper Produced.	Yield.	Selling Price per Pound.	Total Receipts.	Cost of Ton of Ore Stamped.						Total Cost per Pound.	Total Cost per Ton, Milled.	Net Profit.	
							Mining.	Transport. to Mill.	Surface Expenses.	Stamping per Ton.	Improvements.	Smelting and Brokerage			Per Pound.	Per Ton, Milled.
	$	Tons.	Lbs.	%	Cts.	$	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	$	Cts.	$
1897 ..	980,000	394,296	5,109,663	0·650	11·23	574,783·65	56·30	4·54	17·13	23·94	10·75	17·03	10·01	1·30	1·22	0·16
1898 ..	980,000	370,767	4,377,399	0·590	11·83	518,219·14	66·77	5·55	22·34	24·11	19·18	16·04	13·01	1·54	—1·18	—0·14
1899 ..	980,000	380,781	4,675,882	0·614	17·15	802,804·51	78·58	6·50	25·02	23·35	20·62	17·04	13·93	1·71	3·22	0·40
1900 ..	980,000	410,674	4,930,149	0·600	16·41	809,177·00	76·85	6·92	26·73	24·70	27·75	14·70	14·80	1·78	1·61	0·19
1901 ..	980,000	409,124	4,686,889	0·570	15·76	747,177·32	82·87	7·68	27.67	21·98	46·72	14·07	17·73	2·02	—1·73	—0·20

BALTIC MINE.

							(k)									
1899 ..	1,000,000	35,411	608,570	0·858	16·93	107,896	261·7	15·00	100·0	40·00	.....	.....	.....	.....	.....	.....
1900 ..	1,000,000	85,598	1,735,060	0·979	16·49	297,180	160·0	15·52	63·9	41·40	.....	29·60	.....	.....	.....	.....
1901 ..	1,000,000	114,703	2,641,432	1·150	16·43	442,551	171·3	14·99	53·18	41·08	391·0	33·57	.....	.....	.....	.....

FRANKLIN MINE.

							(a)	(b)								
1897 ..	2,000,000	132,026	2,908,384	1·10	11·05	320,917·33	2·03	(d)	(d)	54·00	(d)	32·71	10·71	2·36	0·34	0·07
1898 ..	2,000,000	116,696	2,623,702	1·12	12·07	317,917·63	1·77	(d)	(d)	51·02	(d)	34·29	9·39	2·11	2·68	0·61
1899 ..	2,000,000	89,789	1,230,000	0·68	16·48	202,647·81	(d)	(d)	(d)	32·30	(d)	32·28	(d)	(d)	(d)	(d)
1900 ..	2,000,000	268,571	3,663,710	0·68	16·20	594,252·36	1·72	(d)	(d)	30·34	0·04	23·79	17·90	2·41	1·70	0·27
1901 ..	2,300,000	313,562	3,757,419	0·83	16 09	828,045·91	1·23	(d)	24·75	25·75	1·00	16·42	15·92	2·59	(d)	(d)

OSCEOLA MINE.

1897 ..	2,275,000	443,080	9,500,000	1·072	(d)	1,338,056·11	(d)	(d)	(d)	25·57	17·64	(d)	11·32	2·43	2·76	0·59
1898 ..	2,325,000	505,008	11,800,000	1·168	(d)	1,549,820·12	(d)	(d)	(d)	28·94	18·10	(d)	9·98	2·33	3·15	0·74
1899 ..	2,328,750	546,320	10,950,000	1·002	(d)	1,791,471·01	(d)	(d)	(d)	26·30	13·29	(d)	11·48	2·30	4·92	0·98
1900 ..	2,397,500	683,006	11,200,000	0·819	(d)	2,136,253·02	(d)	(d)	(d)	27·20	27·68	(d)	13·92	2·28	5·15	0·85
1901 ..	2,397,500	793,207	13,723,571	0·865	13·90	1,984,437·14	(d)	(d)	(d)	(d)	60·95	(d)	14·64	2·53	0·005	0·09

QUINCY MINE.

							(e)	(f)							(i)	(i)
1897 ..	1,450,000	542,623	16,924,618	1·56	11·07	1,890,238·64	1·73	(d)	(d)	(d)	34·03	39·53	6·91	2·16	4·27	1·33
1898 ..	1,450,000	543,592	16,354,061	1·54	12·14	1,986,116·81	1·65	(d)	(d)	(h)22·28	39·59	34·23	8·17	2·39	3·97	1·16
1899 ..	1,450,000	559,164	14,301,182	1·27	17·13	2,450,178·66	1·81	(d)	(d)	(h)22·19	72·39	27·50	10·96	2·81	6·17	1·58
1900 ..	1,450,000	558,723	14,116,551	1·26	16·67	2,353,416·59	2·08	(d)	(d)	(d)	108·3	28·17	13·63	3·44	3·04	0·77
1901 ..	1,450,000	586,266	20,540,720	1·19	16·02	3,399,574·80	1·81	(d)	(d)	(d)	18·87	23·28	9·61	2·23	6·94	1·61

TAMARACK MINE.

1897 ..	1,500,000	611,539	20,000,000	1·63	11 32	2,267,340·75	(e)1·81	(d)	(d)	26·41	33·51	59·08	9·18	3 00	2·14	0·70
1898 ..	1,500,000	670,832	22,500,000	(d)	(d)	2,381,388·95	1·79	(d)	(d)	22·40	(d)	(d)	(d)	(d)	(d)	(d)
1899 ..	1,500,000	631,090	17,750,000	1·40	(d)	2,952,098·91	(d)	(d)	(d)	22·73	63·49	(d)	12·46	3·50	4·17	1·17
1900 ..	1,500,000	625,422	18,400,000	1·47	(d)	3,299,077·26	(d)	(d)	(d)	31·48	(d)	(d)	11·41	3·36	6·52	1·92
1901 ..	1,500,000	626,905	18,000,852	1·43	14·22	2,627,954·35	(d)	(d)	(d)	24·95	44·87	(d)	11·67	3·35	(l)4·48	(l)1·28

WOLVERINE MINE.

(g)						(a)										
1897 ..	600,000	82,270	2,237,698	1·36	11·12	252,088·37	1·38	(d)	23·15	29·19	5·52	33·98	8·47	2·30	2·65	0·73
1898 ..	600,000	130,089	3,470,927	1·33	11·43	399,368·77	1·19	(d)	23·51	36·63	47·42	33·33	9·73	2·60	1·70	0·45
1899 ..	600,000	184,799	4,700,373	1·27	14·35	675,859·08	1·00	(d)	19·66	36·68	5·83	34·00	7·71	1·96	6·64	1·69
1900 ..	600,000	184,594	4,756,646	1·29	16·86	806,810·32	1·12	(d)	24·01	41·19	36·67	32·34	9·67	2·46	7·20	1·85
1901 ..	600,000	190,104	4,907,646	1·29	16·74	828,797·32	1·16	5·94	24·16	36·89	14·56	30·06	8·84	2·28	7·90	2·04

(a) Sales of copper and interest. (b) Includes underground and surface expenses and costs of stamping. (c) Includes transportation to mill and surface expenses. (d) Not stated in the reports. (e) Not including interest. (f) Includes mining, transportation to mill, surface and stamping costs. (g) Fiscal year ending June 30. (h) Included under mining costs. (i) Exclusive of interest and income from real estate. (k) Not including assessments. (l) Not deducting extraordinary construction account from annual profits.

now has an extensive equipment. No stoping was done in the South Kearsarge branch, although it is stated that a large amount of good ore was opened up during the year. Three of the four new stamps were erected and the whole capacity of the new mill will be ready for operation by the middle of 1902, when the old mill will go out of commission. Important savings of copper were effected by the new stamps which promise to materially reduce the cost of production when the mill is under full headway. The company was unfortunate last year in that it

adhered to the policy of holding its copper for 17c., with the result that much of its product had to be sold later in the year at a greatly reduced figure. The average price obtained was 13·9c., while other mines marketed their output at 16c. or more. The year's development of the Baltic mine has been highly satisfactory and in harmony with the general views that have been expressed by the management of the company. The average yield of copper per ton of rock stamped was 23 lb., compared with 19·58 lb. in 1900 and 17 lb. in 1899, while the output for the year was 2,641,432 lb., against 1,735,060 lb. in 1900. The first head in the new stamp mill was started in December and two more will be in operation by the middle of the present year. Underground the mine has been opened on a large scale, and when the improvements in the surface plant are completed, it may be expected that the Baltic Co. will become one of the leading copper producers in Michigan. The Tamarack Mining Co. reports for the year 1901 an average price of 14·22c. realized for copper during the year. The dividends were declared from surplus. The No. 5 shaft at the close of 1901 reached a depth of 4,938 ft. The Quincy Mining Co. paid from the earnings of 1901 in dividends $1,000,000. Part of the year's earnings of $1,424,542 were retained in the treasury to increase the surplus and to provide money for the erection of a coal unloading and storage plant, a new dock, and a railway extension at Torch Lake, all to be constructed during 1902. The Wolverine Copper Mining Co. is erecting a modern mill containing two heads of stamps which will have a capacity of 1,000 tons of rock daily, an increase of 50% over the capacity of the two small heads of stamps now in use. The new mill site is on Traverse Bay, the foundations are completed and structural steel work being put into place. The mill is expected to be in operation by July 1, 1902. During construction dividends have been limited to $2 per share, payable half yearly. At the Atlantic mine the installation of a new "Ingersoll-Sargent" cross compound air compressor has greatly facilitated operations. Its capacity is 4,670 cu. ft. of free air per minute, at 75 lb. pressure, and at 75 revolutions per minute. New rolling stock was purchased for the railroad, enabling it to transport rock for the Baltic mine. The Mohawk Mining Co. has completed the structural work of its new stamp mill at Traverse Bay, and it is expected that it will be entirely completed by July, 1902. The 16-mile railroad connection between mine and mill is operated under lease, by the Hancock & Calumet R. R. During the latter part of the year, 170 tons of "Mohawkite" were shipped to the special reduction works at Newark, N. J. The net value per ton of this mineral did not approach that of the trial shipment to Swansea, Wales; $75 per ton being the best net price realizable at the present value of copper. While the veins of "Mohawkite" persist with depth, they vary greatly in size and value. The new mill of the Adventure Consolidated Mining Co., for which the structural steel work was completed and the machinery nearly all on the ground in December, 1901, has three Allis-Chalmers stamps, fitted with coarse rock screens, round mortars, jigs, slime tables, and six Wilfley concentrators. The rock bins have a capacity of 4,500 tons equal to three days' supply. The Arcadian Copper Co., which has expended more than $1,000,000 in development work during the past few years, has closed its St. Mary's shafts and confined its work to the old mine or Douglas shafts. The

Arnold Mining Co. has reduced its force to 12 men and has apparently abandoned hope of success in its mining operations. The Centennial Copper Mining Co. plans to erect a new mill of 2 heads of stamps at Torch Lake during 1902. The result of work on the Kearsarge Lode during 1901 has been so satisfactory that all work on other lodes has been indefinitely suspended. The Isle Royale Copper Co. started its new mill in May, 1901, and during the year stamped 185,175 tons of rock with a yield of but 11·75 lb. of copper per ton. Recent cross-cuts have resulted in the development at depth of the Grand Portage Lode at a distance of 200 ft. west from the Isle Royale Lode, which shows slightly better returns in copper than the latter. The cost of mining and stamping a ton of rock is $1·863. Late in December, 1901, an important consolidation was effected resulting in the organization, with a capitalization of $28,500,000, of the Copper Range Consolidated Co., which purchased for $1,000,000 of its stock the Baltic Co., and for $1,500,000 stock the Copper Range Co. Thirty-five thousand $100 shares were offered to the public at $40 per share and with the balance of the treasury stock such other mines as the Trimountain and Champion mines may subsequently be purchased.

Montana.—The production of the individual mines in this State, from 1895 to 1901, inclusive, is given in the subjoined table:—

COPPER PRODUCTION IN MONTANA. (POUNDS OF FINE COPPER.)

Mines.	1895.	1896.	1897.	1898. (d)	1899.	1900.	1901.
Anaconda	99,775,394	125,350,693	131,471,127	107,214,059	107,914,857	(e)	f101,850,224
Boston & Montana	60,746,000	60,250,000	60,000,000	62,000,000	79,000,000	66,200,000	f58,028,746
Butte & Boston		4,500,000		7,000,000		16,950,000	
Butte Reduction Works	3,390,000	4,225,647	7,888,795	9,685,088	10,049,629	12,455,772	17,969,663
Colorado Sm. & Mg. Co	7,750,000	9,090,680	8,911,578	7,657,938	9,572,155	11,453,940	f7,465,260
Hecla Cons. Mining Co	239,681	312,445	215,431	121,039	155,719	131,494	108,671
Parrot	7,257,000	8,045,648	14,824,487	12,444,828	10,625,696	(e)	f10,167,850
Montana Ore Purch'g Co	14,861,000	15,049,066	13,047,648	13,084,000	15,360,679	22,257,563	f29,896,980
Other Mines	750,000	4,242,583	804,474	(b)	5,775,716	125,011,944	f3,386,021
Totals	194,768,925	a228,958,164	c237,158,540	c216,979,334	237,983,951	254,460,713	229,870,415

(a) In addition to 818,531 lb. of Canadian copper smelted by the Montana Ore Purchasing Co. and deducted in the above table, there was also deducted 1,000,000 lb. more of foreign copper estimated as having been included in the aggregate of the above returns, leaving the net amount 228,958,164 lb. (b) Included in reports of smelters itemized above. (c) Totals reported by E. B. Braden. (d) The individual reports include some copper derived outside of Montana, wherefore their sum exceeds the total as given. (e) Included under "Other Mines." (f) Estimated.

Prepared by George W. Winter.—The production of copper in Montana, during the closing months of the year, shows a heavy shrinkage due to the companies controlled by the Amalgamated Copper Co., the extensive repair work at the various properties on the hill partly accounting for the decreased production of copper. A drainage system has been established to have the mine water taken care of by two central points. At the 2,200-ft. level of the High Ore mine a pumping plant is being installed capable of handling 4,000 gal. in 24 hours. The Mountain Consolidated, Diamond, Green Mountain, Wake Up Jim, and the two Grey Rocks will be drained through the High Ore mine. At the 1,200-ft. level of the Leonard Shaft of the Boston & Montana Copper Co. a compound condensing pump (duplex) is being installed with a daily capacity of 1,000 gal. for that lift; this pump is intended to drain a large area of its territory, the 1,200-ft. level of the Leonard being connected with the two Colusa's, Piccolo, Comanche, Gambetta, and Mountain View mines. The works of this company at Great Falls

is being generally overhauled and enlarged and the improvements will be completed early in January, 1902. At Anaconda the upper works has gone out of commission, while the lower works is running at about two-thirds of its capacity. Work on the new Washoe smelter of the Amalgamated Co. is being completed. This plant, which is probably the most complete and modern in the country, will probably be in full operation by the spring of 1902. The smelter of the Montana Ore Purchasing Co., at Butte, was partially destroyed by fire in April, 1901; aside from the curtailment of output due to the fire, the works has been busy to its total capacity and two new converters have lately been added. The Butte & Boston smelter operated continuously during 1901 with the exception of about 30 days, when it was idle through labor troubles, its chief ore supply coming from shafts No. 1 and No. 3 of the Silver Bow and East Grey Rock mines. The Colorado smelter also was idle for a short time from the same cause. A new roaster of an improved turret type, designed by Richard F. Pearce, is giving great satisfaction. The Parrot Silver & Copper Co., during the fall of 1900, lost through a fire their entire headworks equipment which was replaced during 1901. A steel gallows frame with a height of 100 ft. to the sheaves has been erected over the main shaft; the total weight of frame is 125 tons, with a safe load capacity of 50 tons. A first motion hoist, 28×96 in., inclosed in an engine house, and an iron compressor house, both of modern brick, stone, and iron construction, are among the improvements, the total cost being about $250,000. Of the independent copper properties of the camp, the Speculator is the most important; during the year 200 ft. was added to the shaft, making it 1,400 ft. deep; 300 miners are employed; the property is operated as a close corporation, and can show a larger net profit than any other single mine of the camp, the net profits for the year approximating $1,000,000. The Farrell Copper Co., one of the recent enterprises, has started three shafts on the flat, a short distance east of Meaderville, one of which has reached a depth of 600 ft. Two long-distance electric-power transmission lines bringing power from a distance of about 60 miles have their wires strung to Butte, ready for operation. The following statements of net profits were taken from the books of the county assessor, as returned by the various companies for the fiscal year ending June 30, 1901: Anaconda Copper Mining Co., $5,571,815; Boston & Montana Con. C. & S. Mining Co., $7,042,300; Butte & Boston Con. C. & S. Mining Co., $586,055; Colusa Parrot Mining & Smelting Co., $245,400; Colo. Smelting & Mining Co., $303,620; Montana Ore Purchasing Co., $1,250,000; Parrot Silver & Copper Co., $510,195. The courts have been largely occupied with the various suits between the Montana Ore Purchasing Co. and the Amalgamated Copper Co., several new suits were instituted during the year, which have yet to come to trial. The properties of W. A. Clark and the Butte Reduction Works were operated continuously throughout the year. During the latter months of 1901 not to exceed 50% of the normal force of miners found employment in the mines of the Amalgamated Co., with the single exception of the Gagnon mine, which worked full handed, maintaining its maximum production, and possibly the Parrot, which also produced continuously.

Nevada.—Shipments of copper ore from Good Springs, Lincoln County, were made during 1901 by seven different mines, to the new terminus of the Eastern

California railway. The greatest depth thus far attained in any mine is 750 ft., and at that depth no water is found. In Lyon County the Excelsior Copper Mining Co., operating the Bluestone mine, 5 miles southwest of Yerington, completed the erection of its 150-ton water-jacketed smelter. The ores of this mine are said to be copper oxide and carbonates, and average 10% copper. Early in 1902 the Nevada Consolidated Copper Co. will start work on a large scale on the McConnell mine. Many promising copper properties have been discovered in the new Tonapah district. The Nevada Copper Co., of Humboldt County, completed the erection of its 50-ton smelting furnace, early in 1901, and during the year made a number of shipments.

New Jersey.—The attempts made during the latter part of 1901 to operate the new plant of the Arlington Copper Co., at Arlington, proved unsuccessful from various causes, including difficulties in leaching. The plant is composed of the following machinery: One 350-H.P. Babcock & Wilcox boiler, with Kent regenerative fire-box; a 500-H.P. compound Erie City engine, connected direct to a 240-volt, 1,250-ampere, Crocker-Wheeler dynamo, switch-board, pumps, air-compressor, etc. All machinery is electrically driven, consisting of mine-hoist, No. 5 Blake crusher, one set of Allis-Chalmers rolls, two 10-ton per hour Kent mills, grading screens, and a Brown roasting furnace, 200×10 ft. hearth area, four 125-ton leaching tanks, and a 30,000-gal. stock solution tank. An acid-proof pump circulates solutions, and a series of 128 electrolytic cells connected in multiple, with lead anodes and cathodes, presenting about 6 sq. ft. of area each, are housed in a separate stone and steel building.

New Mexico.—Phelps, Dodge & Co. accomplished considerable development work on the Modoc mine, Grant County, during the year; elsewhere in the same county the Clifton Copper Co. completed and put in operation its new concentrating plant, which includes a crusher, a set of rolls, two Huntington mills, two Wilfley and two Standard concentrating tables. At Lordsburg the Lena Mining Co. completed its concentrator at an expense of $100,000, and another Lordsburg company was erecting a smelting plan comprising two cupola furnaces, to be used either as lead or copper stacks. The Jura-Trias Co., of Bernalillo County, completed and put in operation its reverberatory furnace, and during the latter part of the year began the erection of another reverberatory. The product from the reverberatory operation consisted of two-thirds black copper and one-third white metal. This company mines its own coal. During the latter part of the year the Santa Fé Gold & Copper Co., of Santa Fé County, produced an average of 10 tons of matte per 24 hours, from ores averaging 4·75% copper, and silver and gold valued at $1·50 each per ton. The cost of mining and smelting was $7 per ton. The slag losses were less than 0·5% copper. The mine and smelter is 20 miles from the Atchison, Topeka & Santa Fe R. R., and wagon haulage of coke, etc., adds greatly to treatment charges. The Rio Hondo Copper Co. during the year began the construction of a smelter, and the Fraser Mountain Copper Co. started the construction of a concentrating plant and matting furnace.

North Carolina.—(By W. H. Weed.)—In the Gold Hill district, which between 1842 and 1893 produced over $3,500,000 in gold, and was then abandoned owing to the presence of copper in the ore, the Union Copper Co. has made ex-

tended development. Its smelter was blown in September 20, 1901, and high-grade matte is now being shipped. The smelter contains 2 forty-ton furnaces, and is equipped with the latest type of roasters. The concentrator handles 250 tons of ore per day; $1,600,000 has been expended, and there is said to be $2,000,000 of ore on the dump. There are 12 shafts on the property, three of which are on the Big Copper vein, which has been traced for a distance of 3,000 ft. The Ore Knob mine in Ashe County, which has been abandoned for a number of years, resumed operations late in 1901, and the company owning the property is said to be erecting water-jacketed furnaces of the Garretson type to smelt its low-grade ore. This mine was worked by a Baltimore company when copper was selling for 8 to 9c. per lb., and $210,000 of dividends were paid as a result of its operation. The ore runs about 5% copper. The coper mines of the Virgilina district have been mentioned elsewhere in this volume under the caption "Virginia."

Tennessee.—In the Ducktown district, according to reliable reports, the Tennessee Copper Co. has spent nearly $3,000,000 on its plant and properties, and the Ducktown Sulphur, Copper & Iron Co., $1,000,000. These two companies employ nearly 3,000 men. The last named company treats from 280 to 300 tons of roasted ore daily, producing about 3,000,000 lb. of copper per year, and distributed dividends amounting to $140,000 for 1900 and 1901. Its cost of producing copper has been estimated at 10c. per lb. The Tennessee Co., owning 13,157 acres, began work in July, 1899, and 18 months later had 800,000 tons of ore blocked out. Its plant is very complete. The shaft houses contain crushers, rotary screens, Robins picking belts and 500-ton ore-bins, besides power and air compressor plants; 7·5 miles of standard gauge railway have been laid connecting the shafts, roast yards and smelter with the Atlanta, Knoxville & Northern R. R. The ore is roasted under sheds with a capacity of 83,000 tons. The smelter contains two water-jacketed blast furnaces 56×180 in. at tuyeres, and 18 ft. from tuyeres to charging floor, two converter stands, with six shells 7 ft. in diameter and 10·5 ft. long, which are handled by a 40-ton electric crane with a 50-ft. span. There are the usual accessories of electric slag cars, clay mills, etc. The power house has four 250-H.P. boilers, supplying two Nordberg engines. The estimated cost of production of copper by this company is 9c. per lb.

Utah.—The total production of copper for 1901 was 20,116,979 lb., against 18,504,726 for 1900, an increase of 1,612,253 lb. The Daly-West Mining Co. produced during the year 1,326,448 lb. copper from 31,344 tons of lead-silver ores and concentrates. The Horn Silver Mining Co. during 1901 produced 577,578 lb. copper from 1,410 tons of ore containing gold, silver, and lead. The Utah Consolidated Gold Mines, Ltd., which owns the Highland Boy mine, produced 9,043,967 lb. copper from its own ores, and during the year Bessemerized the matte smelted by the Bingham Copper and Gold Mining Co., producing therefrom an additional 1,041,801 lb. copper. The Bingham Co. is building its own converting plant, which will be in operation early in 1902. The Quincy Mining Co. in 1901 produced 984,169 lb. copper from 39,209,925 lb. of dry ore containing 9,826,007 lb. lead, 1,650,738 oz. silver, and 1,568·4 oz. gold. From January 1 until April 1,

1902, when the mine was sold to the Daly-West Mining Co., the Quincy Mining Co. produced from 16,023,819 lb. dry ore, 333,295 lb. copper, 4,021,979 lb. lead, 546,172 oz. silver, and 616·92 oz. gold. During 1901 considerable additions were made to the Salt Lake smelters. The American Smelting & Refining Co.'s Mingo and Hanauer plants were dismantled, and the Germania will probably be shut down when the new 1,000-ton plant is completed, probably in July, 1902. The new plant of the United States Mining Co., which owns the Centennial-Eureka mines at Tintic, is expected to be completed by September, 1902. This plant will consist of pyritic blast furnaces and converters and will have a capacity of 850 tons per day. The capacity of the Bingham smelter is about 400 tons of ore per day, and that of the Highland Boy about 500 tons of ore per day. The detailed statement from the reports of Utah copper mining companies will be found elsewhere in this volume under the caption "Gold and Silver Mining in the United States."

Vermont.—The Copperfield mines, at Copperfield, Vt., owned by Mr. George Westinghouse during 1901, pumped out the mine, straightened and widened the shaft so as to permit an output of at least 300 tons of ore per day, and began the erection of a smelter, which was not finished and in operation during the year owing to the difficulty in getting deliveries of material. The copper furnaces are two, of about 150-ton capacity each, and were erected by the Colorado Iron Works, of Denver, Colo.

Virginia.—(By W. H. Weed.)—The Virgilina copper belt is situated on the State line between Virginia and North Carolina, on one of the lines of the Southern R. R., 160 miles west of Norfolk. Although known for 40 years or more, the lack of railway facilities and the general disinclination of capitalists to invest in Southern mining properties retarded development until a few years ago. The investment of over $1,000,000 in the field in the past two years, together with the active opening up of its veins, erection of mining and milling plants, and the employment of several hundred people, has brought the region into prominence. Active development has been confined to a radius of 8 miles from Virgilina, in which area there are now 14 mines being operated, four of which are steady producers; 17,000 tons is given as a rough estimate of the ore shipped during 1901, but this is scarcely a fair estimate as the ore must be concentrated before shipment, and the only mill so far erected was not started until last fall. The ores so far mined average about 3% copper, but shoots of high-grade ores (5 to 25%) occur in all the veins so far opened. The ores consist of copper glance and occasional bornite in a white quartz vein matter with admixed talcose altered country rock. The gold and silver values vary but slightly in the different veins, the gold averaging less than $1 per ton, and the silver 6 to 10 oz. per ton in the ores shipped. The High Hill concentrator, working on an ore carrying 5·9% copper, 2 oz. silver, and 0·04 oz. gold per ton, effects a concentration of 11 tons into one, the concentrates carrying 40 to 50% copper, 0·24 oz. gold, and 20·3 oz. silver per ton. The shipping ore carries 4 to 5% iron and 68 to 75% silica. The ore is extremely siliceous and unfit for smelting without concentration. The high-grade ores are shipped directly to the New York works or to the Norfolk smelter. The deepest working of the Virgilina district is that of the

Holloway mine in North Carolina—510 ft. deep. The Person Co. has two shafts 150 ft. and 225 ft. deep, respectively. The High Hill (or Virginia Co.) in Virginia, two shafts of 231 ft. and 339 ft. depth. Numerous shafts from 50 to 150 ft. deep have been sunk on other properties. The favorable labor conditions, cheap fuel, proximity to tide-water, smelting plants, and railway communication all indicate that the ore can be mined, milled, and shipped profitably even at the price of copper prevailing early in 1902. The possible production of the field for the year 1901 to 1902 has been estimated by Caracristi at 4,500,000 lb. at a cost of 9c. per lb.

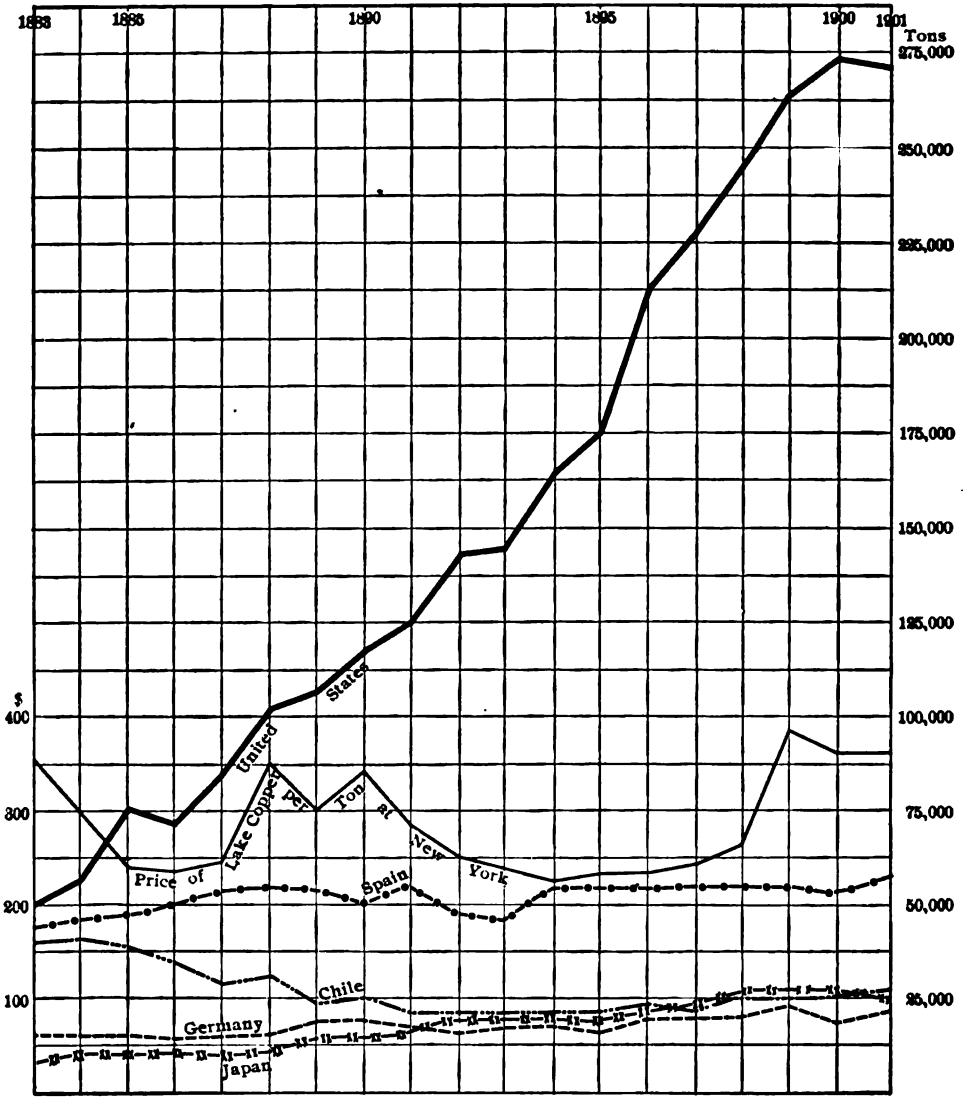
Washington.—Shipments of copper ore were made in the winter of 1901 by sleighs from the Republic camp to the Granby smelter at Grand Forks, British Columbia. The Kettle Valley Lines Railway connecting Grand Forks with the Republic camp will be completed early in 1902. The Tacoma smelter received the greater part of its ore supply from the islands and coast of British Columbia. The California mine on the line of the Kettle Valley Railway, made some shipments of ore to the Granby smelter. The values are principally gold, with some copper and silver, and it is reported that ore from the lower levels assays as high as $239 per ton.

Wyoming.—(By Wilbur C. Knight.)—During the year upward of $1,000,000 was spent in connection with the properties of the Sierra Madre Mountains. The Ferris-Haggerty mine remains as the greatest property yet discovered in that district. The Boston-Wyoming smelter, at Encampment, with a capacity of about 50 tons, was blown in last summer and worked until about the holidays. At first most of the ore was furnished from the New Rambler mine in the Medicine Bow Mountains, but later several properties about Encampment furnished ore, and especially the Ferris-Haggerty. On account of a long haul and bad mountain roads it was decided to construct a wire tramway about 16 miles in length, to be completed in July, 1902, at a cost of $275,000. The tramway is to be divided into four sections and will be partly operated by steam power. The Ferris-Haggerty Co. has entered into an agreement to furnish this tram with 200 tons of ore per day at $4 per ton for the haul. The discovery of various precious metals associated with the copper ore in the Rambler mine has been of very unusual interest. It is now definitely known that the ore contains platinum, iridium, osmium and palladium. These metals are not uniformly distributed through the ore and various samples assayed often show palladium, while others platinum alone. The majority of assays, however, show all four elements.[1] Prof. Wells has already shown that the platinum occurs in the form of sperrylite, and it is quite probable that the palladium also will be found as an arsenide belonging to the same mineralogical group. In the Laramie Mountains considerable prospecting has been followed. At Tie Siding, a Carboniferous or Permian grit has been opened that contains metallic copper and cuprite disseminated through the stratum. The metallic masses are of considerable size, those found on the surface weighing up to 100 lb. In the vicinity of Halleck cañon, about 50 miles N.E. of Laramie, are many promising copper prospects.

[1] See also, under the caption, "Platinum," elsewhere in this volume.

Copper Mining in Foreign Countries.

Argentine.—Late in 1901 the Capillitas Copper Co., Ltd., capitalized at $3,000,000, was organized in London to operate the Capillitas and Atajo mines



The World's Production of Copper in Metric Tons

and the Pilciao and Constancia smelters in the Province of Catamarca. The smelters are about 30 miles from the mines and aggregate eight reverberatory

furnaces. It is stated that the Capillitas ores average 23% Cu, with some gold and silver.

Australasia.—The copper production of Australasia showed an increase of 7,875 tons in 1901, the total production of the metal amounting to 30,875 tons against 23,000 tons for 1900. The old Wallaroo & Moonta mines in South Australia materially increased their output, while considerable additions came from Mount Lyell, in Tasmania; Cobar, in New South Wales; and Queensland, which in 1900 shipped little of the metal, multiplied its output very considerably.

The copper produced in New South Wales during the year 1901 amounted to a total valuation of £413,302, against a total valuation of £428,036 for 1900, showing a decrease of £11,999. The number of men employed in the copper industry during the year 1901 is estimated at 2,964. The re-opening of the Kawau mine, on Kawau Island, in 1900, after its complete abandonment for 40 years, revealed an interesting deposit of native copper, formed by the action of the sea water on the sulpho-salts of copper and the subsequent decomposition of the copper chlorides by the iron present in the mine. Owing to litigation, the

THE WORLD'S COPPER PRODUCTION, 1897—1901. (*a*)

Countries.	1897.		1898.		1899.		1900.		1901.	
	Tons of 2240 Lb.	Metric Tons	Tons of 2240 Lb.	Metric Tons.	Tons of 2240 Lb.	Metric Tons.	Tons of 2240 Lb.	Metric Tons.	Tons of 2240 Lb.	Metric Tons.
Algeria	*Nil.*	*Nil.*	50	51	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*	*Nil.*
Argentina	200	203	125	127	65	66	75	76	780	793
Australasia	17,000	17,272	18,000	18,288	20,750	21,082	23,000	23,368	30,875	31,371
Austria-Hungary	1,655	1,681	1,540	1,565	1,505	1,529	1,355	1,377	1,335	1,356
Bolivia	2,200	2,235	2,050	2,083	2,500	2,540	2,100	2,134	2,000	2,032
Canada	5,905	5,999	8,040	8,169	6,730	6,838	8,459	8,595	18,282	18,575
Cape of Good Hope										
Cape Company	5,290	5,375	4,660	4,735	4,140	4,206	4,420	4,491	4,000	4,064
Namaqua	2,150	2,215	2,400	2,438	2,350	2,388	2,300	2,337	2,400	2,439
Chile	21,900	22,250	24,850	25,248	25,000	25,400	25,604	26,016	30,805	31,299
Germany—Total	20,145	20,467	20,085	20,407	23,460	23,836	20,310	20,635	21,720	22,069
(Mansfeld)	(17,960)	(18,247)	(18,045)	(18,334)	(20,785)	(21,118)	(18,390)	(18,684)	(18,780)	(19,082)
Italy	3,480	3,536	3,099	3,088	2,965	3,012	2,753	2,797	3,000	3,048
Japan	23,000	23,368	25,175	25,578	28,310	28,763	27,840	28,285	27,475	27,916
Mexico—Total	11,370	11,553	15,668	15,919	19,005	19,310	22,119	22,473	33,813	33,943
(Boleo)	(10,170)	(10,334)	(9,436)	(9,587)	(10,222)	(10,386)	(11,119)	(11,297)	(10,783)	(10,956)
Newfoundland	2,519	2,559	2,407	2,446	2,956	3,003	2,883	2,929	2,756	2,800
Norway	3,450	3,505	3,615	3,673	3,610	3,668	3,935	3,998	3,375	3,429
Russia	6,025	6,121	6,000	6,096	7,210	7,325	8,000	8,128	8,000	8,129
Peru	1,000	1,016	3,040	3,089	5,165	5,248	8,220	8,352	9,520	9,673
Spain-Port.—Total	54,060	54,925	53,225	54,075	54,220	55,088	52,872	53,718	53,621	54,482
Rio Tinto	33,900	34,442	33,705	34,244	34,370	34,920	35,732	36,304	35,348	35,916
Tharsis	12,000	12,192	12,000	12,192	9,448	9,599	7,965	8,092	7,427	7,546
Mason & Barry	4,300	4,369	3,600	3,658	3,600	3,658	3,460	3,515	3,729	3,789
Sevilla	810	823	800	813	1,200	1,219	1,460	1,483	1,292	1,313
Sweden	545	554	480	488	520	528	450	457	450	457
Turkey	.....	.....	.....	.....	.....	.....	2,304	2,341	1,639	1,665
United Kingdom	555	564	640	650	637	647	765	777	600	610
United States	223,825	227,420	239,241	243,069	259,517	263,685	270,588	274,933	266,716	270,998
Totals	406,069	412,818	434,330	441,284	468,679	476,194	487,993	496,819	523,162	532,148

(*a*) The figures in this table are taken from the annual metal circular of Henry R. Merton & Co., except where returns have been received by THE MINERAL INDUSTRY direct from official sources.

shaft on this mine was opened beyond the shore line, and after its abandonment the sea washed over and into the old workings and the chloridizing action of the sea water had full sway. The Cobar district of New South Wales presents many serious restraints to profitable copper working. The ores are so siliceous that direct smelting is impossible except at the Great Cobar mine. In concentrating, the losses are 50%, and when this loss is deducted from 3·5% Cu, the average copper content of the ore, and the scarcity of water, the heavy cost of shipping

the concentrates and smelting them elsewhere is taken into account, little profit remains. While the ores of the Great Cobar Copper Co. are of no higher grade than those of the rest of the district, the mixture of the gold-bearing ores from the oxidized surface zone, and the lower sulphide ores make an almost ideal smelting mixture. If the Cobar Chesny mine could profitably concentrate its siliceous ores, it has millions of tons in sight, but their concentration at present with 50% losses, makes profitable working out of the question. The slump in copper compelled the closing of all but the Great Cobar mines during the latter part of 1901, and this mine is working with reduced forces only for the purpose of completing contracts made some years ago for future deliveries to America. The Lloyd mine at Burraga is still working even with copper at its reduced price. This mine has now reached a depth of 1,750 ft., the width of the lode averages 5 ft., with a face of ore 700 ft. long on the line of the lode. The mine produced 21,000 tons of ore in 1901. A new plant was erected during the year at a cost of £32,000, and 500 men are employed. The new mining district near Bungendore, on the Goulburn-Cooma railway continues to look promising. The deepest shaft, 163 ft., follows a lode 25 ft. in width which assays 15% Cu. The Mount Fischer Proprietary Co. expects to erect a smelter on its property early in 1902. The lodes of this district run northward through slates and limestone, and appear to be true fissures.

There were 3,061 tons of copper produced in Queensland during 1901, against 384 tons of copper ore for 1900, a great increase of production due to the Mount Garnet, the Chillagoe Railway & Mines, Ltd., and the Einasleigh Freehold Copper Mines, Ltd. The Mount Garnet Freehold Copper & Silver Mining Co., Ltd., furnished an output of 1,462·3 tons of copper, and 311,586 oz. silver worth £163,000 from 37,179 tons of ore during the year. The smelters of the Chillagoe Railway & Mines, Ltd., after treating 8,129 tons of ore for a yield of 367 tons of copper, 15,721 oz. silver, and 75 oz. gold, of a total money value of £23,792, were closed down. The Einasleigh Freehold Copper Mines, Ltd., began to smelt its ores toward the close of the year, and treated 1,009 tons of ore for a yield of 104 tons of copper, and 1,330 oz. silver, of a total value of £6,600. Smelting operations were then suspended pending the completion of the tramway to the Chillagoe Railway. The Queensland Copper Co. acquired the Mount Perry and Ried's Creek Copper and Gold Mining Co. during the year and prosecuted active work on the Mount Perry mine, unwatering the old shafts, erecting a 60 to 80-ton water-jacketed smelting furnace, and connecting mine and works by a tramway. The production of the Normanby, Harpur's Hill, and Great Freehold mines in the Mount Perry district, was treated at the Aldershot works. The ores of Cloncurry were shipped to Wallaroo, South Australia, and as cost of transport is high, only the very rich ores could be shipped. The last consignment of 528 tons of ore forwarded in 1901 to the Wallaroo smelting works, by the Hampden Copper Mines, of Cloncurry, North Queensland, contained an average of 36·5% Cu, and after deducting smelting charges yielded £10,624, an average of £20 2s. per ton. They are reported to have stacked up at the mines 4,967 tons of second and third-class ores, containing gross values of £28,808. During the latter part of the year a new copper find was reported on the Malbion. Fifty

tons of ore lying on the surface were estimated to contain 40% copper. Reports from the Walsh and Zinaroo mineral field for 1901, estimate copper rock produced at 44,854 tons, with a yield of 2,369 tons of copper, valued at £150,978.

The Mount Lyell Mining & Railway Co. is still the most prominent copper company in Tasmania. In addition to the South Tharsis property, it purchased the Royal Tharsis in 1901. Reports for the fiscal year ending June 30, 1901, for the various mines show the following: Mount Lyell Mining & Railway Co. produced 9,243 tons of blister copper containing 9,132 tons fine copper; 619,734 oz. silver; and 22,911 oz. gold; the amount paid in dividends was £110,000, and a bonus of £13,750. The amount of ore treated at the reduction works for the quarter ending December 31, 1901, was 92,899 tons, from which 2,579 tons of copper, 160,102 oz. silver, and 5,002 oz. gold, the whole valued at £221,134, was produced. The number of men employed in mines and on railway was 1,993. The North Lyell mine shipped to Kelly's Basin 9,243 tons of ore, and to the Mount Lyell smelters 30,083 tons. This company is erecting a smelting plant at Crottyton, where a branch line connects the site selected with their permanent way. The Mount Lyell Blocks has completed the erection of the winding, electric, and compressing plant purchased from the Volunteer Gold Mining Co., at Lefroy. The mine produces about 70 tons of ore per day. The Lyell Tharsis mine produces about 60 tons of ore per day from open cutting and stoping. Systematic prospecting of the Birthday Copper Syndicate property on the coast about 20 miles south of Marquarie Heads, has revealed promising copper lodes, and extensive development of the property comprising 510 acres, will be made by the company.

Austria-Hungary.—The copper mines in Graslitz-Klingenthal, Bohemia, which were abandoned for 200 years, were re-opened in September, 1901. Considerable development work has been done, sinking straight shafts, making air connections with the old workings, and drifting and cross-cutting with the aid of machine drills. The ore lies in a formation of argillaceous slate from 12 to 15 ft. in width. The force of 80 men at present employed will be increased to from 1,500 to 1,600 when the smelting and ore-handling machinery is erected early in 1902. The production of copper for 1900 amounted to 141 metric tons for Bosnia, and 9,890 metric tons for Herzegovina.

Bolivia.—The copper formation of this country now being extensively developed at Corocoro, extends from Atacama, Chile, almost uninterruptedly through all the intermediary provinces to Corocoro, Bolivia, and thence northeast until it finally ends at Apolobama, in Peru, following the eastern chain of the Andes, as well as the spurs of that range. Early in 1901 the Bolivian Co., organized by Sir Martin Conway, obtained important mining concessions from the Government for a consideration of one-third of the annual net profits of the company, and in July, 1901, a scientific expedition equipped for an absence of a year was dispatched into the interior. This concession lies between the crest of the Andes and the great Amazonian plain, and between the rivers Kaka and Beni, and the river Pando or Tambopata, an area of over 10,000 square miles. During the fiscal year 1900-1901 the Government granted 1,172 permits for tin and copper mining, covering an area of 31,315 hectares, against 669 per-

mits covering an area of 15,295 hectares for the previous fiscal year. In 1900 Bolivia exported through Antofagasta, Chile, 178 metric tons of copper ores, and 38 metric tons of silver and copper ore, besides 87 metric tons of copper smalls and 0·868 metric tons of pig copper, the total value of the fine copper contents exported for the year being placed at $451,000.

Canada.—(By W. M. Brewer.)—The production of copper in British Columbia for 1901 was 40,951,196 lb., against 18,919,820 lb. for 1900, an increase of 22,031,376 lb., due to the activity in Grand Forks and Kettle River mining divisions of the Boundary Creek district. The ores of this district are mined by quarrying on the surface or on the pillar and stope method underground, by which it is practicable to open stopes from 40 to 125 ft. wide, and of the same length, with air drills giving a service of from 50 to 100 tons of ore per shift. The costs of mining have been reduced to $0·75 per ton, and at the British Columbia Copper Co.'s smelter the single furnace nominally rated at 300 tons of ore per day has averaged a burden of 367 tons for 11 months, and in December averaged 425 tons per day, reducing the smelting costs for the year to less than $2 per ton. This smelter at Greenwood was blown in on February 18, 1901, and treated during the year 117,565 tons of ore. The Granby Consolidated Copper Co., which owns and operates the Knob Hill and Old Iron Sides mines, treated 230,928 tons of ore in 1901 against 62,387 tons in 1900, the highest daily average of the two furnaces in blast being 633 tons. This company has increased its smelting facilities to 1,300 tons of ore per day instead of 650 tons in 1900, and has also installed a Bessemerizing plant of two stands of converters to produce blister copper from the 50% copper matte formerly shipped. The Le Roi Mining Co., Ltd., in the Rossland district, reports for the fiscal year ending June 30, 1901, a production of ore shipped to the Northport smelter of 202,583 tons of ore averaging $13·16 per ton in value. The working costs were: $4·14 per ton, mining; $0·51 for freight; $4·83 smelting charges; $1·23 for shipping and refining the matte; total, $10·72 per ton. Average profit, $2·44 per ton. The average content of the ore was 1·33% Cu, 0·35 oz. gold, and 0·6 oz. silver per ton. Owing to a strike at the Northport smelter, lasting from July to October, 1901, shipments were not made during that time. The Le Roi No. 2 mine shipped to the smelter during the year, 24,689 tons of ore valued at $435,005 at a total cost for mining of $277,624. The ore averaged $9·18 per ton gold, $0·92 silver, and $7·55 copper. Costs per ton for stoping and loading on cars were $2·90; development, $0·125; machinery and plant, $0·15; surface work, $0·30; mine equipment, $0·10; freight and treatment, $6; reductions from gross metal values, $1·98 per ton; total, $11·56; leaving a net value per ton of $6·09. The mine has a capacity of 250 tons of ore daily. The Hall Mining & Smelting Co., in Nelson district, B. C., was running during the year chiefly on custom ores, but in October, about 13,000 tons of ore from the Silver King mine owned by the company were treated for a yield of 6·5% copper and 37·78 oz. silver per ton. Of the mines in the Southeast Kootenay district the North Star mine paid in dividends during 1901, $135,500, and the St. Eugene, at Moyie, $210,000. Nearly all the ore bodies in British Columbia are lenticular, and like those of Vancouver Island, the gold-copper ores are sulphides. The Boundary district ores, to a great extent pyrrhotite, and some

chalcopyrite, average $2 per ton in gold (though sometimes as high as $15), about 2% Cu, and low silver values. Ores from the west coast of Vancouver Island are chalcopyrite, and vary from 4 to 16% Cu, about $2 gold, and run low in silver; the east coast ores are chalcopyrite and pyrrhotite in a quartz and heavy spar (baryta) gangue, and average $5 in gold, 6 to 8% Cu, and low silver values; the Texada ores, principally bornite, assay from $4 to $20 gold, about 5% Cu, and low in silver. Of the mines on Texada Island, the Marble Bay mineral claim shipped about 12,000 tons of ore during the year partly to the Van Anda smelter, and during the latter part of the year to Tacoma, Wash. The ores average from 0·24 oz. to 0·9 oz. gold, 5 oz. silver, and 7% Cu (dry assay). The Van Anda Copper & Gold Co.'s plant comprises a large wharf, warehouse, 125-ton smelter, sampling works, and assay office complete, and the company owns and operates the Copper Queen and Cornell mines; the ores average $25 per ton in value. Other mines on the island shipped small amounts of ore to the Van Anda smelter during the year. On Vancouver Island, the Monitor Mining Co. shipped, during the year 996 short tons of ore, carrying 174,261 lb. Cu. The Tyee Copper Co., of Mt. Sicker made extensive development work and some ore shipments to the Tacoma, Wash., smelter during the year. This company will erect a smelter at Ladysmith early in 1902, of sufficient capacity to handle its own product as well as custom ore. A Montana syndicate also will erect a smelter during 1902, at Osborne Bay, a short distance from the Tyee smelter. The Three Jays Copper Co., on Alberni Canal, has made shipments to the Tacoma smelter during 1901, and having completed the aërial tramway, bunkers, etc., has chartered steamship capacity for monthly shipments of 3,000 tons to the Tacoma smelter, during 1902. The increase in production of Ontario for 1901 was 9,074,000 against 6,728,000 for 1900, the increase being due largely to the richer nickeliferous mattes shipped from the Sudbury district, although the non-nickeliferous mines on the north shore of Lake Huron also increased their output. The Westmoreland Copper Co., near Dorchester, New Brunswick, is reported to have expended over $240,000 on mines and reduction plant, which includes dynamos, furnaces, crushers, and a series of 80 precipitating tanks. It is alleged that the mine has been developed to a depth of nearly 200 ft., and that the horizontal workings aggregate some 7,000 ft. in extent. The 150-ton plant of the Intercolonial Copper Co., at Dorchester, N. B., which was started in the latter part of the year, comprises crushers, roasting furnaces, and 50-ton leaching vats. The strong solutions from the sulphuric acid leaching are passed through an electrolytic precipitating process, while the wash waters are precipitated on scrap iron. The trial run was satisfactory. The mine has nearly a mile of underground workings, and the ores consist of chalcocite and copper carbonates in sandstone.

The Cape Breton Copper Co., at Coxheath, Nova Scotia, during 1901, continued development of its low-grade ore deposits, assaying 3% Cu, 0·09 oz. gold, and 4 oz. silver. Concentrating tests show concentrates assaying Cu, 9·9%; Fe, 27·3%; SiO_2, 35%; while the tailings contain 1% Cu. The Colonial Copper Co., at Cape d'Or made extensive developments on zones in the trap rock, which carry metallic copper. About 70 men are employed in summer and 15 men in winter.

The company expects to become a producer in 1902. The Copper Crown Mining Co. did a small amount of work during the summer of 1901.

Chile.—(By W. E. Mathewson.)—The two large refineries at Guayacan and Lota produced their usual quota of Chile bars during 1901; the Guayacan refinery may have increased its output somewhat on account of the heavy shipments of matte from the Panulcillo furnaces which ran well throughout the year. The Guayacan and Lota plants produce the bulk of the bar copper exported from Chile, which is shipped by nearly every steamer of the Pacific Steam Navigation Co. leaving Valparaiso for Great Britain. There were several smaller plants in operation during the year, notably at Huasco, Chanaral, La Serena, Antofagasta, and Gatico. At the plant of the Fundicion Templeman, in Antofagasta, several hundred tons of argentiferous copper bars was produced assaying about 75 oz. silver per ton, all shipped to Great Britain, where this firm is interested in a refinery. At the Playa Blanca establishment of the American Smelting & Refining Co., near Antofagasta, 7,800 tons of argentiferous copper matte were produced, assaying 50% Cu and 390 oz. silver per ton, and shipped to their refinery at Perth Amboy, N. J. The low metal quotations at the close of the year together with the closing of the Playa Blanca plant seriously interfered with the mining of copper ores in the Province of Antofagasta. The bulk of the copper of that province is mined at Chuquicamata, a camp on the spur of the Antofagasta, Chile & Bolivia railway, about 267 km. from the port of Antofagasta. The mines are not yet very deep, 100 m. being the greatest depth attained. The surface ore is peculiar in that it is largely composed of the mineral atacamite, a volatile copper oxychloride. The output of the province was approximately 25,000 metric tons of an average assay of 13% copper. There were a few hundred tons of ore over 15% Cu shipped to Swansea, the balance being smelted locally.

EXPORTS OF COPPER FROM CHILE AND BOLIVIA.

	1897.		1898.		1899.		1900.		1901.	
	Quintals.	Fine.	Quintals.	Fine.	Quintals.	Fine.	Quintals.	Fine.	Quintals.	Fine.
Bar copper.....	418,665	418,665	448,585	448,585	400,955	400,955	442,174	442,174	526,950	526,950
Copper regulus...	86,538	42,661	81,141	41,930	72,006	32,949	105,172	45,236	136,489	62,345
Copper ores.....	94,550	20,786	324,919	64,023	646,028	118,193	439,406	77,652	486,858	90,630
Total.....	.....	482,112	.....	554,538	.....	552,097	.....	565,062	.....	679,925

NOTE.—The quintal is 101·5 lb. avoirdupois.

China.—In the French Province of Yunnan, lying between the Red river of the south, the meridian of Haïphony on the east, and the Blue river, are extensive copper deposits which have been worked by the Chinese for over 1,000 years, to such extent, that the forests have been entirely cut off to provide charcoal for the crude metallurgical processes, and the production of copper to-day is restricted by the lack of fuel. In the twelfth century the production of copper amounted to 6,000 tons, while to-day, it is not more than 1,500 tons. The accessible beds of copper are mostly exhausted, but modern methods and deep mining would probably yield rich returns. The Government has authorized the

construction of a railway from Lao-Kay to Yunnan-Sen, a distance of about 291 miles, and has ceded the operation of the 239 miles of railway already completed from Haïphony to Lao-Kay for 75 years, the contractor to assume the expenses of the whole, and share the profits with the Government. The working and building capital of the contractor amounts to $19,493,000. Besides the copper mines, the completion of this railway will open up extensive deposits of mercury, tin, and coal.

Cuba.—There are a number of abandoned mines in Santa Clara province, some of which are near railway points. Among them are Mina San Juan de la Malaja, 6 miles N.E. of Santa Clara City, the district about Finca San Joaquin, about 30 miles N.E. of Cienfuegos; Mina Santa Rosa, 2·5 miles further east; prospects a few miles west of Cumanayagua; in the northern portion of the district of Trinidad; and there are three prospects near Sancti Spiritus.

Mina San Juan de la Malaja shows on surface a "blow out" 100 ft. across which is composed of yellow iron oxides, hematite, considerable quartz, and some copper carbonate. Sufficient depth has not been attained to determine whether or not there are sulphides beneath the gossan. The strike of the Mina Santa Rosa vein is N.45°W., and it dips steeply to the N.E. The footwall of the vein is composed of feldspathic rock, and the vein is 10 ft. wide, iron stained, and contains copper carbonate ores, iron pyrite, and chalcopyrite. The Finca San Joaquin district appears to be the only one which shipped to any extent. In 1856, 480 tons were shipped to Swansea, Wales, and 300 tons to the United States, the ores averaging 17% copper, with a total value of $12,000. In 1868, 3,253 tons were shipped to Swansea, Wales, for which £54,446 was received; the average copper content was 19·7%. The mines were last worked from 1882 to 1885, and were then abandoned on account of the revolution. The Mina San Fernando vein is in diorite-porphyry; the lodes are nearly vertical, and the gossan consists of iron oxide and quartz, with occasionally a good deal of blende. The copper ores are massive or decomposed azurites, red and black oxides, and purple and yellow sulphurets. At one point the lode measures 30 ft. in width. An analysis of a sample of sulphide ore yielded 8·36% Cu, 57·34% Fe, 0·15 oz. gold, 4·7 oz. silver per ton, and a trace of lead. The Mina San José vein consists of quartz in diorite porphyry, the ores are sulphides, and the mine waters contain a large percentage of copper.

Dutch East Indies.—The Pagoeat Co. is slowly developing a copper property comprising a vein of chalcopyrite and chalcocite ores which is 1·3 m. in width and carrying 10% Cu. The country is dioritic slate and the mineral is in a quartzose gangue. The Bone Co. claim to have an immense deposit of ore carrying 5% Cu. They propose to exploit the north coast of the island, which is called the "Gold coast of Celebes."

Italy.—The Etruscan Copper Estates at Campiglia, 2 miles from the railway station of San Vincenzo, made some explorations of its copper mines during 1901. These ancient mines have been variously reported on by different experts. It is doubtful if any extensive development of the copper mines will be attempted during 1902. The Etruscan Co. has however begun the erection of a reducing plant for their zinc-lead ores, which are found near their copper deposits. The

Libiola Copper Mining Co., Ltd., reports for the year ending December 31, 1901, a net profit of £6,095, from which £3,780 dividends were paid, leaving a balance of £2,831. A final dividend amounting to £2,520, payable in 1902, was recommended; 900 yd. of ground were opened up, and 5,229 tons of copper ore averaging 3·746% Cu, and 22,868 tons of pyrites averaging 47% S, were mined in 1901, against 5,700 tons of ore averaging 4·427% Cu and 26,211 tons of pyrites averaging 47% S, in 1900.

Japan.—For several years past the output of Japan has increased steadily by small margins and now exceeds 25,000 metric tons annually, being about on a parity with that of Chile. The number of producing properties is large, but more than 60% of the total product is contributed by the following mines, arranged in the order of their importance: Ashio mine, in Shimotsuke; Besshi mine, in Iyo; Ani and Arakawa mines, in Ugo; Osarusawa mine, in Rikuchu; Kusakura mines, in Echigo; and Ogoya mine, in Kaga. The Ashio mine which produces about 6,000 metric tons annually is located some 15 miles S.W. of Nikko, and is said to have been worked for a period of more than 300 years. The ore deposits consist of quartz and chalcopyrite veins inclosed between an eruptive rock of liparitic character and hard slate. It is said that the average content of the dressed ore is 15% Cu, while some of the richer material runs as high as 30%. The principal vein averages 12 ft. in width and has been followed in the workings for about two miles. As the deposits are located on the side of a mountain, they are opened by adits; recently, however, the construction of a shaft has been undertaken which will be used to exploit one of the smaller veins. The equipment of the mines is modern throughout and includes electric motors for haulage and electric hoists and pumps. Power is supplied from an hydraulic plant which contains four Pelton wheels and two turbines, developing altogether 450-H.P.

Mexico.—The plant and mines of the Rio Tinto Mexicana Co., a short distance from Chihuahua, formerly owned by an English syndicate which is reported to have spent over $1,000,000 on the property without profitable recovery of the values in the ores, has been purchased from it at a cost of $25,000 Mexican, reconstructed and improved at an expense of $92,000 Mexican, and during the first 14 months of its operation earned the entire cost of plant and mine. As the slags under the English management ran upward of 2% Cu, some idea of the cause of former unprofitable working may be had. The mines of the Jimulco Co., situated about 75 miles south of La Descubridora mines, State of Coahuila, were reported to be in bonanza copper rock during the latter part of 1901. The Descubridora Mining & Smelting Co., in the State of Durango will complete the erection of its new electrical machinery for mines and smelter early in 1902. A company controlled by Pittsburg interests is erecting a 50-ton smelter near Eloro, Durango, which will use hot air in smelting for copper matte carrying gold. El Progreso Copper Mining Co. has been operating the mines in Jalisco during the year and considerable development work has been reported. The Santa Emilia Copper Co. constructed a 50-ton concentrating plant at its mines near Coapa, State of Michoacan, and the product is shipped to the Monterey smelters. La Mina de California Co., of the Guaymas district, State of Sonora, was organ-

ized during the year, with a capital stock of $1,000,000 to operate 20 pertinacias of copper property, situated 3 miles north of the Yaqui river and 3 miles from the town of Cumuripa. The assays are said to average $93 per ton in value, and the company is reported to be erecting a smelter.

The fuel gas plant of the Moctezuma Copper Co., at Nacosari, consists of two sets of two fire-brick lined generators, each 9 ft. 6 in. diameter by 15 ft. high, with a waste heat, vertical, multitubular boiler, scrubber, and Root's exhauster. By altering the exhaust speed the quantity of gas required for the varying power demands is secured. The producer and water gas are stored in separate gas holders and mixed later in fixed proportions. Each set of generators is in operation every other week, and develops 1,000-brake H.P. per hour in eight Crossly, four cycle gas engines rated at 110 H.P. at 200 revolutions per minute, which, in turn, operate eight 65 kw. 260-volt (shunt-wound, for protection against lapses in the gas engines), direct-current, General Electric generators, with a normal speed of 910 revolutions per minute. The consumption of New Mexican bituminous coal (containing 20% ash) is 1·5 lb. per brake H.P. per hour; with wood (scrub oak, etc.), about 3 lb. for the same unit. All of the ore (averaging 76% SiO_2) is concentrated in a mill built in two sections, side by side, which contain the following machinery: two Blake crushers, two sets roughing rolls, one set finishing rolls (in common use by the two mills), 12 revolving screens, 24 Hartz jigs, two sets of 54×8-in. rolls, 5 Huntington mills, 24 six-ft. vanners, with smooth belts, and four with corrugated belts, and 10 Bartlett tables. The saving effected is 90% of the gross contents of the ore. Of the coarse concentrates 40% go direct to the smelter, and 60% are briquetted with 5% of clay. The two elliptical Copper-Queen-type, wrought-iron smelting jackets, measure 42×130 in. cross-section. The smelting charge consists of coarse concentrates, converter and foul slag, calc spar, and "green" and flue-dust briquettes. The matte and slag flow into a tilting well, from which the latter runs continuously to waste, while the former is poured by tilting the well and flows thence by gravity to the two stands of trough-shaped converters, measuring 6 ft. 8 in. diameter by 9 ft. length, each. The converter-lining is lean gold and silver-bearing quartz, which is consumed by the low-grade matte at the rate of 1 ton per ton of copper produced. The converter and stack fumes, are partially recovered from an 8-ft. horizontal steel flue, by a conveyor, and further, from an inclined brick flue 750 ft. long, which empties at the top of the hill into a 70-ft. brick chimney. The production of fine copper during 1901 was 8,614,161 pounds.

The Greene Consolidated Copper Co., of La Cananea, Sonora, produced during 1901, 13,854,170 lb. of fine copper. This company's first copper furnace was "blown in" in December, 1900, the second furnace early in 1901, the third and fourth in October and December, 1901, respectively, and Nos. 5 and 6 were "blown in" early in 1902. The production of copper matte for the first four months of 1902 was 11,758,072 lb.; with silver, 114,426 oz. Before the middle of 1902 the new converter plant with a capacity per month of 6,000,000 lb. of copper matte, from six stands of converters, is expected to be in operation. The following detailed cost table will show expenses of copper production during 1901: Cost of mining, $0·91 per ton of ore; cost of smelting to matte, $2·14 per ton; hauling

from mines to smelter, $0·15; total, $3·20 per ton of ore. As the copper content of the ore averages 159 lb. per ton, the cost per lb. copper produced is $0·0201. The matte shipped contains 1,000 lb. copper per net ton, and the freight to New York is $12 per ton or $0·012 per lb. of copper contained; Bessemerizing costs $5 per ton, or $0·005 per lb. copper; selling commissions $0·005 per lb.; refining $0·0025 a pound, making a total cost of $0·0446 per lb. of copper. The 250-ton copper smelting furnace of the Copete & Melczer Mining Co., of Ures, State of Sonora, was put into operation in May, 1901, and it is reported that later in the year the construction of a concentrating plant was begun.

Newfoundland.—The Cape Copper Co., Ltd., at Tilt Cove, according to its report for the fiscal year ending August 31, 1901, produced at a gross profit of £60,591 which netted £47,909. During the year the East mine produced 54,253 tons of ore, averaging 3·28% Cu. The new South lode produced 10,268 tons of ore, averaging 4·27% Cu by wet assay, and the West lode 3,593 tons. During the year 78,089 tons of ore were shipped from Tilt Cove. The output of the East mine was distributed as follows: 33,922 tons sent to New York and 40,376 tons to Swansea, Wales.

Norway.—The Sulitjelma Copper Works, near Bodö, the largest in Norway, employed nearly 800 men and produced in 1899 about 40,000 tons of copper ores and pyrites. The mine has been considerably developed during 1900 and a much larger output is anticipated. The Lyngen Copper Works east of Tromsö is now connected by an aërial tramway with the Kaafjord valley and during 1900 produced 17,500 tons of raw ore which was subsequently concentrated. The copper deposits at the mine were only discovered in 1897, and have not yet been fully developed. The Killingdal mines produced 17,700 tons of ore in 1900 against 21,194 tons in 1899; the Drogset mine, at Meldalen, produced 2,718 tons pyrites containing copper, and the Ytteröen mine 1,300 tons pyrites. In addition to the above the mines at Alten, in Finmarken, the Bosmo pyrites mine, and the Rorös, near Trohdhjem, employing 600 men, all contributed to the copper production of Norway. A 50-ton Elmore process concentrating mill is working in Norway on ores containing iron and copper pyrites, and carrying value in gold. The ore is delivered to three batteries of five stamps, with screens of 20-mesh, which deliver to three McDermott "sizers" or submerged screens of 30-mesh. The coarse material goes to a Wilfley table, and the fines from the screens are treated on 3 six-foot Frue vanners, the tailings of which pass through the oil-process plant, consisting of two units of three mixing cylinders each.

Peru.—An extension of the Central Railway now completed from the seaport of Callao to Aroya, is projected to Cerro de Pasco, a distance of about 75 miles, which would cost about $3,000,000 because of the great difference in altitude (Callao at sea level and Cerro de Pasco at an elevation of 14,300 ft.; total distance by survey 214 miles). The proposed charge of $12 per ton freight from Cerro de Pasco to Aroya, against $34 to $39 the present charge for transportation on the backs of llamas should net a handsome profit to the enterprise. In 1900 about 12,000 tons of copper ores carrying 30 to 35% copper, and 4,800 tons of copper matte were shipped for export from Cerro de Pasco, a tonnage which could be largely increased with railway facilities. The Cerro de Pasco district is about

1 mile square, and the ore deposits are reported to be practically inexhaustible. Of the 576 mines of the district, 480 are owned by a mining company in which J. B. Haggin is the largest stockholder. It is reported that this mining company is erecting smelting furnaces of the capacity of 1,000 tons of ore per 24 hours, and a converter plant.

A local syndicate capitalized at $600,000 in Lima, Peru, has undertaken the completion of the Rumiallana tunnel, abandoned 20 years ago with but 900 ft. penetrated, of the total of 9,000 ft. for the purpose of draining the mines of the Cerro de Pasco district. This syndicate is said to have contracted with various mines as follows: 50% of all the ores removed from the cuts and drifts along the route of the tunnel are to be the perquisite of the syndicate, while the mine owners are to give to the syndicate 20% of their total ore mined in consideration of the drainage of their properties. Should the individual owners wish to lease their entire workings to the syndicate, the latter are to assume all expenses of operation and account to the individual owners for 40% of the total ore removed by such operation. The Haggin Mining Co., however, denies the validity of such tunnel concession so far as its mines are concerned. It is reported that a syndicate is being formed to operate the rich copper mines in the Yauli district, 120 miles from Callao, at 13,400 ft. above sea-level. These mines are near a station of the Trans-Andine Railway, begun some 25 years go.

Philippine Islands.—Extensive copper deposits are reported on the Island of Mindanao, in the region inhabited by the Moros, who have crudely worked these deposits for years. The Chinese and Philippine miners pound the ore to crumbs on anvil-shaped pieces of metal, the smaller pieces are then run through rolls. These rolls are stone or iron, in some cases, and disc form in others, and are turned around by water-buffalo power. Large furnaces for intensely heating the rock to soften it for crushing are found, and several smelting furnaces are in operation, the most successful ones owned by Germans. One German concern gets a plentiful supply of excellent native miners for a few cents per day each. Both gold and silver as well as copper, are found in Mindanao.

Russia.—In the provinces of Semipaletinsk, Okmolinsk, and Karkaralinsk, in Siberia, important deposits of copper are being worked. These copper ores contain but little gold and silver. Nearly 600 licenses have been issued by the Government for the operation of the coal and copper mines of these provinces. The Russian production of copper for the year 1899 was 7,323 metric tons (447,082 poods), against an importation for the same year of 11,957 metric tons (730,000 poods), while in 1900 the production is estimated at 8,128 metric tons.

South Africa.—The report of the Cape Copper Co. for the year ending April 30, 1901, for South Africa, and August 31, 1901, for London and Newfoundland, shows a credit balance of £444,629, which includes £195,734 from the previous year. Of this, £11,191 was paid for income tax and £258,750 for dividends; £10,000 to sinking fund, leaving £164,688 to be carried forward, out of which a final 8s. dividend is to be paid January 1, 1902. During the year at the Ookiep mine 19,174 dry tons of ore and 2,521 tons of slimes assaying 10% copper were treated. The Nabaheep mine furnished 17,272 long tons of ore of 6·41% copper

wet assay. The entire output of the two mines was treated at the local smelting works. At the Spectakel mine 439 dry tons were raised and at the Narrap and Trial mines satisfactory progress has been made. The Johannesburg Consolidated Investment Corporation, capitalized at 3,000,000 marks, has leased through Goerz & Co. the copper mining rights to the 16,800 square miles of territory owned by the German Colonial Co. in German Southwest Africa. This territory is bounded on the north and south by the Swakop and Knisib rivers, respectively, on the west by the English territory of Walfish Bay, and on the east by the sixteenth degree of longitude east of Greenwich. The Colonial Co. is to receive a bonus of £30,000, and 2·25% of the gross annual revenue from the mines. The copper deposits in question are reported to be very extensive and of great value. The asbestos and graphite deposits in the same territory have been leased to another syndicate capitalized at 80,000 marks. The Consolidated African Copper Trust, capitalized at $3,000,000, has been organized to work the large deposits of copper which are reported to have been discovered in Rhodesia. It is said that the De Beers Co. and the Consolidated Goldfields of South Africa are interested in the new concern.

Spain.—The new smelting plant of the Rio Tinto Co., Ltd., strictly American in design and furnaces, was put into operation in January, 1902. The plant consists of two water-jacketed furnaces, each 160×42 in. at the tuyeres, with forehearths, 12 ft. in diameter, and 4 ft. deep, for the separation of matte and slag; and two No. 8 Connellsville blowers. The six 7-ton Bessemer converters (in two stands of three each) are of the trough type, 80 in. diameter by 120 in. long. The charge to the shaft furnaces consists at present of low-grade precipitates (55% Cu), high-grade pyrite ores (55% Cu), and sufficient quartzose pyrite ore (2 to 8% Cu, and 30 to 90% SiO_2, balance pyrite) to yield a slag of about 37% SiO_2. Five hundred tons of material (excluding the Welsh coke) are treated daily. Complete separation of the matte is prevented by the high density of the ferrous-silicate slag, and from 0·5 to 0·65% Cu remains in the slag. Of the three grades of precipitates produced containing 93%, 85%, and 55% Cu, respectively, the first two grades are shipped to Cwmavon, and the last 55% with its 3 to 4% arsenic, graphite and silica, is smelted with the ores in the blast furnaces to produce 50% matte. The highly siliceous quartzose ores are used for converter lining. The converter bars containing small amounts of silver and gold beside the copper are shipped to Cwmavon, Wales, for refining. The efficiency of precipitation of the Rio Tinto Co.'s leaching process amounts to a consumption of but 1·2 lb. of iron for each pound of fine copper produced. The Rio Tinto Co., Ltd., during 1901, realized on sales of copper and other items, including balance carried forward from 1900, a total of £1,505,692. Of this sum the following amounts were set aside: For the redemption of the 4% bonds, £65,800; plant out of use and charged off, £78,454; coal exploration, £10,000; depreciation of securities, £8,500; credited to reserve fund, £40,000; credited to provident fund, £4,000; total, £206,754. Out of the balance, amounting to £1,279,250, interim dividends of 2s. 6d. on the preference shares, less income tax (total, £38,424), and 35s. on the ordinary shares, free of income tax (total, £568,750), were paid, and dividends of 2s. 6d. on the preference shares (total, £38,255),

and 37s. 6d. on the ordinary shares (total, £609,375) were recommended, leaving a balance of £24,445 to be carried forward to 1902 revenue account. The total quantity of ore extracted during 1901 was 1,928,776 tons with an average copper content of 2·627%. The pyrites ore invoiced to consumers in England, Germany, and the United States amounting to 641,935 tons, contained 14,248 tons of copper, which, with the 21,100 tons extracted at the mines, made a total output for the year of 35,348 tons of copper. It was estimated that the reserve heaps at the mines contained 136,457 tons of fine copper, while the stocks at the company's works at Cwmavon, consisting of refined copper, copper in process, in precipitates and in matte, amounted to 6,062 tons. The Tharsis Sulphur & Copper Co., Ltd., reports for 1901 a total extraction of mineral from its Tharsis, Lagunazo, and Calañas mines of 732,389 tons against 770,995 tons in 1900, a decrease of 38,606 tons during the year. Calañas increased its production during the year by 29,970 tons, while Tharsis and Lagunazo fell off 68,576 tons owing to the almost complete exhaustion of the copper ores in these two mines. There still remains a quantity of ore carrying 49% of sulphur, but very small values in copper, from which the company hopes to derive some profit in future years. The exported ore amounted to 424,434 tons, while 307,955 tons were treated locally, from which the Metal works recovered 7,427 tons of fine copper as against 7,967 tons in 1900, a decrease of 540 tons due to lesser copper content of the ores as well as to smaller amount of ore treated. Total profits were £335,867, of which £42,081 was charged off to profit and loss account, £250,000 paid out as a 20% dividend, and £43,786 carried forward. Among other copper mines of Spain which are producers now or will shortly become so are the Escurial, Escurial Extended, La Recompensa, Huercal, and Coruna mines.

Turkey.—Rich copper mines, near Arghana Maden, which are owned by the Government, produce annually about 1,500 metric tons of ore, which is shipped through Alexandria to Great Britain. The ores are so rich that they are easily concentrated to 80% matte in one smelting operation. The copper mines at Tokat, and those near Dede Agatch are of smaller extent, and the ores are refractory. The Espie Bay Mines Development Syndicate, Ltd., of England, is operating the copper mines near Tereboli. The long abandoned Maaden-Keni copper mines near Baibourt on the Trebizond road, were re-opened under Greek management during 1901, and about 3,750 lb. of copper per month was extracted, amounting to a total production for 1901 of over 22 tons valued at £1,600, all of which was exported to Russia.

The Copper Markets in 1901.

New York.—The course of the copper market during the year 1901 was followed with marked attention, not only by those directly or indirectly interested in the production and consumption of the metal, but also by the public at large. For the first time in years, the exigencies of the stock market had to be taken into consideration in trying to form opinions on the probable course of copper, although in the end, it is the inviolable law of supply and demand which governs the price of this as well as any other staple article.

Business in this country was very satisfactory, and the industries consuming

copper had their full share of activity. Both the wire and brass mills were very busy throughout the year, and while prices for the former product ruled comparatively low, those for the latter were well maintained, owing to the elimination of some sharp competition by the formation of the American Brass Co., which controls a large number of well equipped mills throughout the country. The railroads called for heavy quantities of the metal for use in the construction of locomotives and cars, and large orders were placed by shipbuilding firms for use in the construction of vessels for the Government and the merchant marine. The main increase in consumption, however, came from the electrical industry.

The consumption of sulphate of copper was satisfactory, and though the production is large, the stocks which were carried forward after rather a busy season, are not expected to last very long.

Exports during the year under review showed a marked decrease. In 1900 shipments to European ports amounted to two-thirds of the production; in 1901 to about one-third. The falling off in exports is due to the depressed condition of business in Europe, caused in England by the South-African war, and on the Continent by over-speculation. Naturally, new enterprises in which copper is required were suspended, and the result was a lessened demand on the part of the manufacturers. Aside from this, the disparity between foreign and domestic markets has led to a heavy increase in importations. The decrease in business in Europe was intensified by the reluctance on the part of manufacturers on this side to lay in stocks under present conditions. While thus consumers are practically bare of supplies, there is no doubt that the leading producing interests have been forced to carry the available stocks, which at the end of the year were variously estimated at from 150,000,000 to 250,000,000 lb.

The Amalgamated Copper Co., whose policy influences the market to a great extent, raised its capital from $80,000,000 to $155,000,000, for the purpose of acquiring the outstanding capital stock of the Boston & Montana Mining Co. and the Butte & Boston Co. It now controls about one-fifth of the world's production of copper. Negotiations were at one time under way with the object of having the principal producers join in a movement to restrict production. It is questionable if in the long run the disadvantages resulting from such a measure would not outweigh the advantages.

The year opened with Lake copper selling at 16·75@17c.; electrolytic copper at 16·25@16·375c.; casting copper at 16c. Business was rather dull, but improved during February, and a large demand sprang up for quick shipment. While Lake copper remained practically unchanged at 17c., electrolytic copper advanced to 16·5c. by the end of April. Consumption in this country during the summer months was very heavy, and aided by a fair demand from Europe values were easily maintained. It was not until the end of July that prices commenced to sag, mainly owing to the fact that consumers restricted their purchases to early deliveries. The ruling quotations in September were 16·5c. for Lake, 16·25c. for electrolytic, and 15·75c. for casting copper. In the meantime, the speculative market in London showed signs of weakness and the reports regarding the state of business in Europe were of a most discouraging nature. Exports of refined copper fell off to an alarming extent, while imports continued to increase, and rumors

were put into circulation, according to which the leading producing interests were carrying extraordinarily large stocks. The market recovered from the consequent depression and values kept fairly steady throughout October and November, but it soon became apparent that the Amalgamated Copper Co., which for such a long time had upheld quotations by asking 17c. for Lake and 16·25c. for electrolytic copper, would by force of circumstances be obliged to meet the market. Europe did not send any orders whatsoever; exports were alarmingly small; copper shares on all the exchanges were depressed and stocks continued to accumulate. A sale of a round quantity on private terms, carrying with it as it seems a guarantee of price, was reported at the end of November only to be followed by an open cut of about 1·25c., thus reducing the quotations to 15·375c. for Lake and 15c. for electrolytic copper. This was followed by a cut to 14c. for Lake, 13·875c. for electrolytic, and 13c. for casting copper, and another one to 13c. for Lake copper, 12·875c. for electrolytic, and 12·5c. for casting copper. These prices were freely met by the outsiders, but, naturally, the market was utterly demoralized and business practically at a standstill, consumers preferring to await further developments. The quotations at the end of the year were 12@12·5c. for Lake, 11·75@12c. for electrolytic, and 11·5@12c. for casting copper.

AVERAGE MONTHLY PRICES OF LAKE COPPER IN NEW YORK.

Year.	Jan.	Feb.	Mar.	April	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.
1897	11·75	11·92	11·80	11·48	11·03	11·11	11·11	11·16	11·30	11·18	10·86	10·78	11·29
1898	10·99	11·28	11·98	12·14	12·00	11·89	11·63	11·89	12·31	12·41	12·86	12·93	12·08
1899	14·75	18·00	17·54	18·43	18·25	17·93	18·33	18·50	18·46	17·76	16·93	16·40	17·61
1900	16·33	16·08	16·55	16·94	16·55	16·00	16·16	16·58	16·69	16·64	16·80	16·88	16·52
1901	16·77	16·90	16·94	16·94	16·94	16·90	16·51	16·50	16·54	16·60	16·63	14·39	16·55

AVERAGE MONTHLY PRICES OF ELECTROLYTIC COPPER IN NEW YORK.

Year.	Jan.	Feb.	Mar.	April	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.
1899	14·26	17·02	16·35	17·13	17·20	16·89	17·10	17·42	17·34	16·94	16·49	15·85	16·67
1900	15·58	15·78	16·29	16·76	16·34	15·75	15·97	16·35	16·44	16·37	16·40	16·31	16·19
1901	16·25	16·38	16·42	16·43	16·41	16·38	16·31	16·25	16·25	16·25	16·22	13·82	16·11

London.—January opened with a visible supply of 28,860 tons, compared with 22,817 tons at the commencement of 1900, and with standard copper at about £73 spot and £73 12s. 6d. three months. Owing to the increase of the Bank of England rate of discount to 5% and to the apparent indifference of the American manipulators, values soon became easy and touched £70 12s. 6d. and £71 5s. for the above-named prompts. Consumption during this period was good, but purchases were made only for immediate needs. February commenced with the visible supply at only 152 tons above the previous month's, but prices eased off a shade owing to realizations and a want of speculative interest. On the resumption of buying by parties identified with the Amalgamated Co. there was a slight improvement to £71 15s. cash and £72 7s. 6d. three months, but some "bear" selling soon pushed the prices back about 10s. per ton. There was rather better demand from consumers, and the English Government also bought fair lines for stock. March started with the visible supply at 28,995 tons, against 28,904 tons at

the end of January, and after £71 5s. was done for cash and £71 15s. for three months, dullness again became apparent, and prices were allowed to drift to £67 10s. cash and £68 three months. There was no sign of reaction until the middle of the month, when the statistics showed a substantial decrease and this caused a rally to £69 10s. and £70. Consumers bought freely at the decline, more particularly on the Continent. April witnessed a better speculative feeling, induced by the strength of the share market in America and the intervention of American supporters in the metal market. Prices steadily rose until cash touched £71 and three months £71 10s., but just at the end of the month there was a sudden break to £69 10s. and £70, respectively. Trade with manufacturers was good and they bought freely in all kinds of copper. The War Office and Admiralty also purchased largely, with the result that at the beginning of May there was a better tone prevailing and the market improved to £70 10s. for early delivery and £71 for forward. At this time the Amalgamated Co. and other large producers were offering Lake and electrolytic copper at reduced prices, and most of the chief consumers were speedily filled up. The American railway share market also had a shake up at this time, causing a reaction in the standard market, prices declining to £69 spot and £69 10s. for later deliveries. June statistics gave 27,231 tons as the visible supply, but the standard market entered into a period of inactivity and business became a matter of mere jobbing between insiders; values consequently underwent but very little change, the whole of the fluctuations being covered by 20s. per ton. Trade with consumers was quiet, the chief demand being for copper suitable for electrical and ammunition work. Tough was also scarce owing to the firm attitude adopted by the principal producers. July opened with a dull outlook, the figures giving a slight increase in the world's supply of copper. Standard, after commencing at £68 cash, fell away to £67, three months' metal offering at 10s. advance. American operators gave some support at this level and caused an improvement of about 30s. per ton, but this was partially lost before the end of the month, when the closing rates were £67 10s. cash and £67 17s. 6d. forward. Trade remained quiet and consumers were only buying on a limited scale.

August began with the stock at 27,395 tons, but the metal trade was greatly disturbed by the strike in America among the iron workers and many people took fright and sold copper freely, causing a rapid decline to £65 5s. cash and £65 12s 6d. forward. This level was touched about the middle of the month and reports then spread of further arrangements with the Amalgamated and other large producers; in fact, it was suggested that a giant copper trust was to be formed which would embrace all the largest producers of the world. The rumor was good enough to give speculation a fillip and values speedily recovered to about £67 10s. cash and £67 15s. three months. One of the largest of the European outside producers gave an absolute denial to the report and profit taking soon ensued, causing a setback to £66 10s. and £67. The advance in standard gave users of copper more courage and they bought rather freely. It was also stated that some of the larger mines in America were shut down for a time. September opened with a substantial shrinkage in the visible supply, which stood at 25,821 tons, being a reduction of over 1,500 tons on the month. These figures were

responsible for a rise to £67 10s. cash and £68 three months, but the receipt of the news of the dastardly attempt on the late American President's life was a disturbing factor, and this market, in sympathy with all others, experienced a relapse. Reports then arrived from America predicting an early reduction in price by the Amalgamated Co., and this naturally caused uneasiness among speculators and a want of confidence with consumers. The stock markets in America and in Paris and London quickly gave way to a state bordering on panic, the result being that standard quickly descended to £60 10s. cash. The Amalgamated then publicly announced that they were not going to cut their price, and there was a sharp recovery to £63 5s. cash, £63 12s. 6d. three months, at which the market closed. Demand for consumption up to the time of the publication of the above recorded unfavorable rumors was good, but naturally fell off very materially toward the end of the month. October figures showed a further shrinkage in stocks which stood at 24,765 tons, and values of standard continued to improve until £65 was touched for cash. Renewed selling, based on share movements, then caused a decline to £63, but smelters bought good lines of standard to convert into refined, and an improvement was again made to the region of £65 10s. The dealings were on a large scale and fluctuations were violent. Prices dipped again as low as £62 5s. cash, and £61 5s. three months, only to be followed by an advance to £65 and £64, respectively. November commenced with a large decrease of nearly 4,000 tons in the visible supply and values were strong in the neighborhood of £66 cash and £65 forward, and remained so until just at the close of the month, when a decided raid on forward metal was commenced by one firm who threw large lines of forward metal on the market, much to the bewilderment of the whole of the operators. Sales were so persistent and of such magnitude that we witnessed a time more exciting than has been seen since the break up of the French syndicate. December proved to be the most exciting month of the whole year, commencing with renewed aggressive selling on behalf of a prominent dealer, who in the best informed circles was supposed to be selling on behalf of the Amalgamated crowd, and this hammering continued practically throughout the month with only a few days' intermission, but immediately values showed any signs of steadying a further onslaught was noticeable. Reports from America as to continued reduction in the United Metals Selling Co.'s price also helped to aggravate the weakness of the standard market, and just before Christmas affairs took a still more sensational turn, owing to the suicide of a well-known broker. This was followed by the failure of one of the oldest firms on the London Exchange, which was due to the weight of metal that they were carrying. As their commitments in this article were heavy, there was another setback in values, which on December 20 declined to £48, but later in the day reacted to the neighborhood of £49. The year closed with standard copper selling at £49 2s. 6d. for spot, £49 2s. 6d. for three months also.

Progress in the Metallurgy of Copper during 1901.

The following notes on the progress in the metallurgy of copper during 1901 have been abstracted chiefly from the technical literature of the year in addition to information and criticism which have been obtained by direct correspondence or discussion with practical metallurgists.

Automatic Sampling.—(By Paul Johnson.)—In The Mineral Industry, Vol. IX., is a short description of the automatic sample mill of the British Columbia Copper Co., at Greenwood, B. C. In order to utilize the gravity principle these samplers were designed to avoid elevating the material before it was crushed, and sample cut twice, thus necessitating the lift of 2% of the total ore sampled only, which is crushed to a size below 1·5 in. and is not hard on elevator belts and buckets. The endeavor was made to use construction drawings of the ordinary mechanical samplers, but these took more vertical room than could be spared. The height available was but 36 ft. and it was desired to reject the material direct into the gravity bins after crushing and sampling without further mechanical elevation.

Since erection over 100,000 tons of various ores have been sampled and check-sampled, and actual practice has proved the correctness of the system. The practice at Greenwood is as follows:—

The ore for sampling at the smelter is brought to the upper ore bins, which are six in number, in two parallel rows, side by side, each bin being 50 ft. long; the railroad tracks are over the center lines of these bins. The greater bulk of the ore is delivered to the smelter in dump cars of from 30 to 35 tons capacity, which are unloaded into the bin below by opening two bottom doors. When the ore comes in box cars it must be unloaded by shoveling into the side bin adjoining the one over which the car stands. The ore is withdrawn from the bin through ore gates 3 ft. wide by 2 ft. high into ore scoop cars on rails, which hold from 1 to 1·25 tons of ore and are brought down on a tramway of 1% grade to the top floor of the sample mill. One man can handle two cars, as, when started, they go by themselves. The cars are first weighed on a Fairbanks scale to check the railroad weight scale and then dumped into the large hopper of a No. 5 Gates crusher. Pieces over 11 in. thick are reduced with 16 lb. sledge hammers to enable them to pass the 11 in. opening between the corrugated crusher-head and the concaves of the crusher. The crusher is set to crush to a size of from 3 to 5 in. and corrugated crusher-heads are used. If the pieces do not exceed 10 or 11 in. in size this crusher will easily crush one ton in from 30 to 45 seconds. The crushed material is spouted down to the first Johnson No. 1 sampler, which makes between 6 and 7 revolutions per minute, and cuts out either 10 or 20% for first sample, as desired, and is made large enough to permit the passage of 10 to 11 in. pieces, largest dimension, without catching in the sampler. The rejected 80 or 90% falls through the spout into ore bin No. 1, whereas the sample goes through the sample spout down to a No. 2 Gates crusher. The sample is then crushed in the second crusher to a size of from 0·75 to 0·25 in., and passes through a No. 2 Johnson sampler. This cuts out three samples for each revolution, and makes 9 revolutions per minute; 20% is taken for sample, and

the remaining 80% is rejected to ore bin No. 2. The sample is spouted down to the boot of the elevator and lifted about 55 ft. above the top floor of the sample mill and dumped through a chute spout down to a No. 0 Gates crusher, which crushes the pieces to from 0·25 to 0·5 in. in size. The material is then spouted to a No. 3 Johnson sampler, which makes 12 revolutions per minute and cuts three samples for each revolution, removing 20% for sample. The 80% part is discharged into ore bin No. 1, and the 20% part for sample drops on a sloping feed table which, with a jerking motion, feeds the sample into a pair of 10×16 in. Reliance rolls, which are intended to crush the sample to an average fineness of 0·125 in.; it then passes through a fourth Johnson sampler of the same size as the previous one. The 80% part is again rejected, being dropped directly into ore bin No. 1, and the remaining 20% part is conducted down through a spout and an 8-in. pipe to the sample buggy car holding the final sample, which, when finished, is taken to the quartering plates, and cut down and mixed from 1 to 3 times, according to the size of the sample desired. The sample is then taken to the sample grinder, ground, again mixed and quartered down on the bucking plates, and then ground to pass a 100-mesh sieve. From this pulp, the final sample is taken, generally three bags, filled and sealed; one for the smelter, one for the ore shipper, and the third for umpiring.

By these proceedings the total quantity of the ore received is crushed and submitted to the sampling, and if 10% is taken for the sample after the first crushing, and afterward a 20% part, each time, it will thus be seen that the final sample in the sample car will weigh 0·1×0·2×0·2×0·2 or equal to 0·0008 ($\frac{1}{1250}$) part of the entire lot. If a lot is not large only 0·2×0·2×0·2, or 0·008 ($\frac{1}{125}$) part of the lot is taken for final sample.

Below are given results of assaying check samples of various lots; two independent samples, *a* and *b*, being taken of each lot, which shows how nearly equal two independent samples may be obtained by this system of sampling.

No. of Lot.	Sample	Weight.	Copper. Wet Ass'y	Gold.	Silver.	No. of Lot.	Sample	Weight.	Copper. Wet Ass'y	Gold.	Silver.
		Tons.	%	Oz.	Oz.			Tons.	%	Oz.	Oz.
1	*a*	32	6·60	0·04	1·00	7	*a*	50	0·88	0·20	0·45
	b	32	6·40	0·03	1·25		*b*	50	0·90	0·18	0·44
2	*a*	65	6·10	0·12	1·80	8	*a*	17	0·00	0·74	5·60
	b	65	6·15	0·12	1·70		*b*	17	0·00	0·72	5·62
3	*a*	110	3·85	0·01	2·17	9	*a*	30	0·00	0·36	2·00
	b	110	3·80	0·01	2·20		*b*	30	0·00	0·34	1·90
4	*a*	150	1·70	0·145	0·34	10	*a*	110	0·00	0·29	9·70
	b	150	1·70	0·150	0·33		*b*	110	0·00	0·27	9·60
5	*a*	27	1·70	0·52	1·30	11	*a*	17	0·00	0·04	25·70
	b	27	1·68	0·48	1·39		*b*	17	0·00	0·04	26·40
6	*a*	33	0·90	0·15	0·41						
	b	33	0·98	0·14	0·42						

The analyses of the ores as sampled above are given in the subjoined table:—

Lot No.	SiO_2.	FeO.	CaO.	S.	Insoluble.	Lot No.	SiO_2.	FeO.	CaO.	S.	Insoluble.
	%	%	%	%	%		%	%	%	%	%
1	33·6	14·8	4·1	10·9	51·6	7	29·6	26·7	Tr.	16·3	84·7
2	52·0	12·6	3·8	Tr.	54·2	8	89·5	3·3	Tr.	1·2	90·2
3	29·5	16·7	17·8	6·4	87·4	9	91·7	2·3	Tr.	0·7	93·0
4	38·0	23·2	13·1	2·4	42·1	10	82·1	4·2	.....	3·3	84·5
5	37·5	19·3	3·4	12·0	50·1	11	68·1	10·1	Tr.	11·6	68·7
6	33·1	26·5	Tr.	18·6	35·4						

Smelting Copper Ores at Greenwood, B. C.—(By Paul Johnson.)—The plant, of which a description was given in THE MINERAL INDUSTRY, Vol. IX., commenced operations on February 18, 1901, with one blast furnace, 42×150 in. at tuyeres, which has been kept continuously in blast, except for nine days for repairs in August. Between February 18 and December 31, 1901, 117,077 tons of ore were smelted in this one furnace, which produced 3,714 tons of matte, assaying from 45 to 60% Cu, from 2 to 6 oz. in gold, and from 10 to 30 oz. in silver per ton. Besides Mother Lode and Boundary ores, some gold quartz ores of 80 to 90% SiO_2 have been smelted, fluxing with the Mother Lode ores. The largest tonnage was put through during December, when 13,098 tons of ore were smelted, averaging daily for the entire month 422·5 tons of ore. The largest tonnage smelted in one day was on January 10, 1902, when 459 tons of ore were put through the furnace. To handle this amount of material and to break up and pile the matte produced, the blast furnace department proper, in 24 hours employed 29 men, *viz.*, 6 charge wheelers, 4 coke wheelers, 9 feeders (on 8 hours' shift), 2 charge weighers, 2 furnace men, 2 matte-tappers, 2 roustabouts, 2 foremen; thus, during December 14·5 tons of ore per man and shift were handled. Counting the total force of the smelter, the sample mill requires 10 men for unloading and crushing ore, sampling and distributing same into ore mixtures, and loading the shipping matte. Engineers, foremen, 1 blacksmith with a helper, and 1 carpenter, add 8 more men to the force, making the total number of men employed, including foremen, 47 men, which at 422·5 tons of ore put through daily, makes 9 tons of ore handled and smelted for every man employed.

The complete assay of three large lots of the iron, lime and sulphur ores smelted is given in the subjoined table:—

	Iron Ore. Sample from 1,000 Tons.	Calcareous Ore. Samples from 1,600 Tons.	Sulphide Ore. Samples from 120 Tons.
	%	%	%
Copper	2·8	2·2	2·7
Insoluble	28·7	35·2	29·8
Fused silica	16·9	29·2	24·5
Iron oxide	32·7	14·7	17·5
Lime	5·6	19·8	16·0
Sulphur	3·7	5·3	13·7
Silver, oz. per ton	0·58	0·48	0·43
Gold, oz. per ton	0·11	0·09	0·15

The character of these ores is not only self-fluxing, but at times rather basic, and sometimes as much as 5 to 6% of quartz ores have been smelted to advantage with them.

Before starting up the furnace it was somewhat doubtful whether or not a higher grade matte than 30 to 35% Cu could be made without resorting to roasting the ore, but actual practice demonstrated that the iron ore, which contains magnetic Fe_3O_4, in smelting, and reducing its iron to Fe_2O_3 for the slag, gives off one atom of oxygen for every molecule of Fe_3O_4, and this oxygen acts as such a powerful desulphurizer that in fact as much as 85 to 90% of the sulphur on the charge has been burned off at times. A 45 to 50% Cu matte was desired, but sometimes it has attained over 60% Cu, with an excess of the iron ore on the charge. It is an interesting fact in connection with making this high-grade copper matte, that whenever the matte begins to come up to 53% Cu and above, the gold will

"lock up" in the furnace in metallic copper bottoms formed. In one week making 58 to 63% Cu matte gold to the value of $6,000 was locked up in the furnace bottom. The following week, using sulphur ores to bring the matte down to 45% Cu all of the "locked up" gold was regained in five days. Silver, however, does not behave in this way.

The Mother Lode ore is exceptionally free from arsenic and antimony, and behaves quite differently in the furnace as compared with the Silver King ore, which I formerly treated at the Hall Mines Smelter, Nelson, B. C., and which ore then carried quite an amount of arsenic and antimony, a purple-red colored smoke emanating from the chimney. When running the Silver King ore metallic copper and speiss separated out as soon as the matte came up to 47% Cu, which raised the furnace and settler bottoms and caused very great trouble by filling up the tap hole, thus menacing the plugging up of the furnace. In Nelson, on this account, the trapped spout was changed to the ordinary way of stopping up the tap hole with clay, and when the furnace bottom was "raising up" inside the tap jacket the furnace was blown through the tap hole for five minutes, the heat produced melting away the metallic obstructions. Using trapped blast with the Mother Lode ore as high as 67% Cu matte in the blast furnace has been made without filling the tap hole with metallic copper.

For its size (42×150 in. at the tuyeres) the furnace has a very unusual record for large tonnage and at the same time clean slags. The coarseness of the ore has more to do with tonnage and to some extent clean slags than anything else under similar circumstances. This was found out when we crushed the ore to 5-in. size, having gotten a wrong crusher head before, which crushed the ore to 2 and 3 in. A few percentages of silica, more or less, in the slag does not "slow up" these big furnaces as quickly as it does small furnaces, nor is an excess of lime as bad. If the iron in the slag comes up to 30 or 32% and silica at the same time is low, say 28 to 30%, a heavy slag is made and a correspondingly poor separation of the matte ensues, which is very troublesome and increases the copper in the slag. Examples of some different kinds of slags made, with the corresponding tonnage and tenor of copper in the slag are as follows:—

April 1, 1901, the slag assayed SiO_2 33·8%, FeO 25·4%, CaO 25·7%, and Cu 0·25%; matte 49% Cu, the tonnage 402 of ore; high lime has a tendency to make the slags clean in Cu.

July 7, 1901, the slag assayed SiO_2 30·9%, FeO 32·5%, CaO 16·8%, Cu 0·44%; the matte 53% Cu, the tonnage 399.

November 7, 1901, the slag assayed SiO_2 42·7%, FeO 21·1%, CaO 20·0%, and Cu 0·33%; the matte assayed 44% Cu, and furnace smelted 393 tons of ore.

January 10, 1902, when the furnace put through 459 tons of ore, the slag assayed SiO_2 37·8%, FeO 24·5%, CaO 20·9%, and Cu 0·35%; the matte assayed 49% Cu.

The concentration has varied from 15 to 70, but when the matte fall is below 2% the furnace does not work well, there is too little heat brought down in the crucible; this is especially pronounced with a rather siliceous slag, which causes the light to go out of the tuyeres and raises the smelting zone.

Slag samples for copper are taken twice daily, but are not assayed by the generally adopted colorimetric method, which as a rule gives too low results. The slag samples are taken every hour, chilled in water, the day and night shift slags being kept apart. Two grams are taken for the determination, dissolved in aqua regia, evaporated with H_2SO_4, diluted and copper precipitated with hyposulphite of sodium solution, the Cu_2S dissolved in HNO_3, and titrated with KCy; this determination takes somewhat over two hours, carrying other work along with it, but it is correct and reliable, and it will check to 0·01% Cu, and where there is very little copper on the charge it is important to have accurate determinations of the slags and to keep them low in copper, as 0·1% Cu makes quite an important item. These daily slags are then put together, and once a week the average of all the slags is made for gold, silver, and copper. The slags, as a rule, have been very clean, the copper varying between 0·3 and 0·037%; gold between 0·0025 and 0·0035 oz., and silver between 0·04 and 0·07 oz. per ton. Of course one is allowed more copper in the slag and still considered to do good work making a 50%-Cu matte, than in making a 30%-Cu matte. A former rule was that good smelting was accomplished when one had only 0·1% Cu in the slag for every 10% Cu in the matte. Thus, making a 30%-Cu matte allowed 0·3% Cu in the slag, etc.

The amount of coke used is from 11·5 to 12% of the weight of the ore. The blast used is from a No. 7·5 Connersville blower, making 155 revolutions per minute, and giving 80 cu. ft. of air per revolution. The blast pressure averages 1·75 in. mercury, equal to 14 oz. Feed height above tuyeres varies from 4 to 8 ft.; when little sulphur or much coarse ore, feeding high; when much sulphur or much fine ore, feeding low. The best feed height for good running was found to be from 7 to 8 ft.

In running the furnace 3-ton charges are put in at the feed floor by feeders, and not by mechanical devices which are costly in diminished tonnage, bad working of the furnace, and yield dirtier slags.

A charge comes down to the tuyeres in 45 minutes; slag and matte run together continuously through a trapped spout into a water-jacketed forehearth on wheels, inside dimensions being 8×5·5 ft.×3 ft. deep. The matte, having a sp. gr. of from 5 to 5·3, sinks to the bottom, and the slag of a sp. gr. of about 3·4 to 3·5, overflows at the furthest end into a large settling pot, and from this into the granulating flume. The matte is tapped at intervals into matte pots, and their contents poured into matte molds 2×5 ft.×4 in. deep, thus cooling off the matte quickly and delivering it into the shape of cakes from 1 to 1·5 in. thick; these matte cakes when cooled are knocked on the top side with sledge hammers and broken up into 3×5-in. pieces and shipped in bulk in box cars, the lots averaging 30 tons. This does away with a crusher and sacking and makes the matte pots last longer.

During the latter part of 1901 the capacity of the smelter was doubled by the construction of new sets of lower ore bins, twelve in number, with an increased storage capacity of 5,000 tons of ore, making a total storage capacity for the lower ore bins of 10,000 tons. Another railroad trestle 560 ft. long has been built between the two already constructed in order to handle over 1,000 tons

daily of material for the smelter by the railroad. The foundation for the furnace building extension and the new furnace are in, and cast iron columns and furnace deckplates are put up. The furnace will be finished as soon as the cold weather allows the building of the brickwork for it. The new No. 7·5 Connersville blower is ready and in place for the furnace. With this second furnace completed, the plant will have a daily capacity of over 800 tons of ore, and together with coke, coal and matte shipped, the railroad will have to handle nearly 1,000 tons daily. The operation eventually of three to four furnaces is contemplated, and it is intended to add a converter plant to run the matte to blister copper, thus saving the freight on the copper to New York and on the refining charges on the copper now in the matte.

Copper Smelting Jackets.—The use of drop furnace bottoms supported by screw jacks resting on and attached to a car, traveling on a track beneath the furnace, came into general use during 1901. Among the furnaces erected with this type of bottom, were the 42×160-in. jackets erected by the Allis-Chalmers Co., for the Rio Tinto Copper Co., Ltd., of Huelva, Spain, and three furnaces built by the Colorado Iron Works, two for Mr. George Westinghouse for erection at Copperfield, Vt., and one for an Arizona company. A patent was applied for on the carriage furnace bottom by a Denver, Colo., mining engineer during 1901. The Mountain Copper Co., at Keswick, Shasta County, Cal., during 1901, adopted the use of water jackets made entirely of copper instead of cast or boiler iron, as formerly. The cost of the copper jackets is said to be $75, as compared with $20 for cast jackets, and they are made in the company's foundry from metal obtained from the cement copper leached at the mine. It is said that the life of the copper jackets is so much greater than those made of cast iron, or the copper-lined jackets, that notwithstanding the greater first cost, considerable economy is effected by their use. The use of copper spouts instead of cast iron ones is also increasing.

Blowing Engines for Copper Smelting.—The United States Mining Co., at Murray, Utah, installed during 1901, three blowing engines, displacing 75,000 cu. ft. of free air per minute at 2·5 lb. pressure, for use in connection with its copper matting plant. The blowing engines are designed by Edwin Reynolds to be driven by cross compound condensing Reynolds-Corliss engines. A comment on the use of blowing engines in preference to rotary blowers is made by Hiram W. Hixon,[1] who states that, irrespective of the work to be done, the blast pressure will depend entirely on the charge burden in any kind of blast furnace work, and that the charge burden governs the reducing action of the furnace altogether. Along these lines the iron industry has raised the charge burden up to 100 ft. to secure the full benefit of the reducing action of the carbon monoxide on the ore. Mr. Hixon further states that by using a blowing engine and consequently high blast pressure in a copper matting furnace run with the intention of producing as high a grade of matte as possible, by the oxidation and elimination of iron and sulphur, it would be impracticable to run a low charge burden in the furnace, and the proper conditions of oxidation of iron and sulphur cannot be obtained with a high charge burden. The reducing action in the furnace is

[1] *Engineering and Mining Journal*, 1901, p. 64.

effected almost entirely by the gases, and when these are permitted to go to waste, reduction ceases.

Hot Blast Stove for Copper Smelting.—An installation of the Bretherton hot blast stove (Fig. 1) has been made at the smelting works of the Val Verde Copper Co., at Val. Verde, Ariz., in connection with a round 48-in. blast furnace. The air supply for the stove is drawn through air jackets situated above the water jackets of the smelting furnace, and the small amount of heat recovered in this way costs but little more than the extra expense of the jackets.

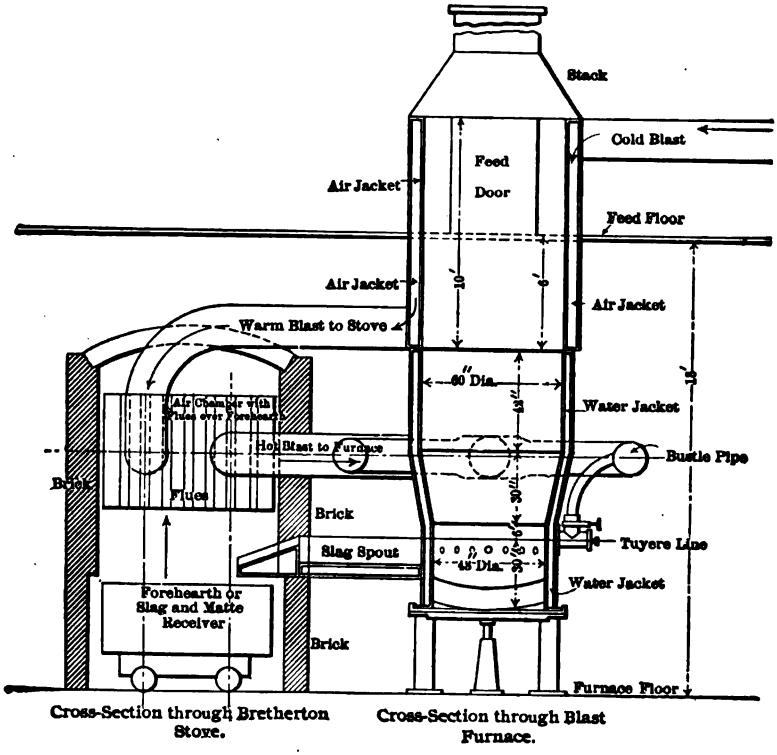


FIG. 1.—THE BRETHERTON HOT BLAST APPARATUS.

As installed by the Val Verde Copper Co., Val Verde, Ariz.

The heat evolved by the matte and slag in the forehearth is passed through the flues of the stove, and if this heat is not sufficient it is supplemented by an extra wood or coal fire. The temperature of blast claimed to be obtainable by means of this stove is 325°F., and the saving of coke by the use of the blast is said to be considerable.

Details of Construction of Furnace Flue for Warming Blast.—This apparatus as shown in Fig. 2 consists of a chamber arranged in the form of a hood over the entire top of the dust flue, for the purpose of abstracting the heat of the flue-dust and gases passing off from the furnace, and incidentally assisting the opera-

tions of the dust chamber by the contact of the hot gases against a cool surface, which tends to throw the dust out of mechanical suspension in the hot waste gases. Four pipes connect the hot air chamber with the bustle pipe of the four furnaces.

Roasting Copper Matte.—To facilitate the roasting of dense copper matte it is sometimes cast in sand beds made of flue-dust from copper furnaces which produces a spongy porous material of one-third the average density of similar matte cooled in iron molds. This porous condition of the material acts very satisfactorily in the subsequent treatment in the fusion furnace, especially when charged with siliceous fines that otherwise would be troublesome. Mr. F. Longford has obtained very good results by casting the matte in this manner. The flue-dust was dampened to pack it and allowed to dry in place so as to avoid the

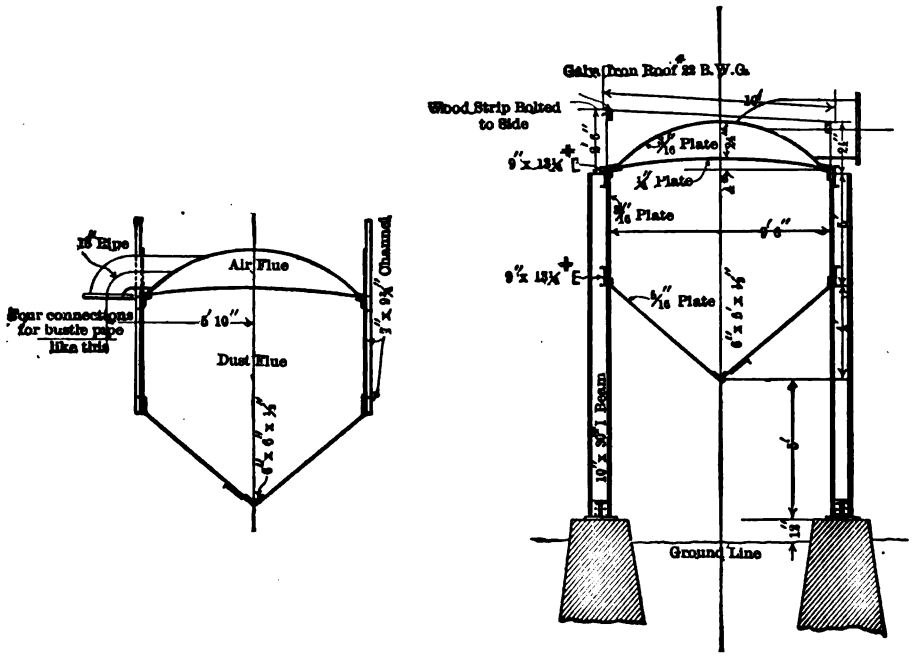


FIG. 2.—DETAILS OF CONSTRUCTION OF FURNACE FLUE FOR WARMING THE BLAST.

danger of violent explosion. The porous condition of the matte is produced by the escape of gas which when set free caused bubbling and miniature explosion.

Customs Decision on Copper Matte and Regulus.—Early in 1902 in an appeal of the El Paso Smelting Works from the decision of the Collector of Customs at El Paso, Tex., to the Board of General Appraisers, it was held that copper matte containing lead is included within the term "copper, regulus of" in paragraph 534, Act of July, 1897, and as such is entitled to free entry. In the subject of this protest the lead contained in a certain quantity of copper matte was assessed for duty at the rate of 1·5c. per lb., under part 181 of the Act of July 24, 1897, which provides "Lead-bearing ore of all kinds, 1·5c. per lb. on the lead

contained therein." The assay of the copper matte in question was 47·64% Cu and 18·43% Pb. The full decision may be obtained by reference to the *Engineering and Mining Journal,* April 19, 1902.

The Thermo-Chemistry of the Copper Bessemerizing Process.—In an article on "Converters for Copper," by M. P. Jannettaz,[2] the thermo-chemistry of Bessemerizing copper matte is given much as follows: Mattes containing copper, iron and sulphur varying according to the nature of the mineral, as well as arsenic, antimony, bismuth, tin, lead, zinc, nickel, cobalt, silver and gold, deport themselves in the converter according to the principle of the maximum work performed, or those compounds are formed which give off the greatest heats of formation. The following table contains a series of columns contrasting the

THE HEAT OF FORMATION OF OXIDES AND SULPHIDES.

Elements.	Typical Formulas of Combination.	Heats of Formation in Calories at 15° C.		Elements.	Typical Formulas of Combination.	Heats of Formation in Calories at 15° C.	
		Oxides.	Sulphides. (a)			Oxides.	Sulphides. (a)
Sulphur	S,R_2	+ 69·2	.....	Iron	Fe,R	+ 65·7	+23·8
	S,R_3	+ 91·8	.....		Fe,R,aq	+ 68·9	.....
Carbon	C,R	+ 29·4	.....		Fe_2,R_3,aq	+193·1	.....
	C,R_2	+ 97·6	−25·4		Fe_3,I_4	+270·8	.....
Silicon	Si,R_2	+219·2	+10·4 (b)	Chromium	Cr_2,I_4-hydr.,O_3	+ 16·4	.....
Phosphorus	P_2,R_5	+365·2	.....	Nickel	Ni,R,aq	+ 61·4	+19·4
Calcium	Ca,R	+131·5	+90·8(c)	Cobalt	Co,R,aq	+ 64·1	+21·9
Magnesium	Mg,R	+143·4	+79·4(c)	Zinc	Zn,R	+ 83·6	+43·0
Aluminum	Al_2,R_3,aq	+398·0	.....		Zn,R,aq	+ 86·4	.....
Arsenic	As_2,R_3	+154·6	+ 90·8	Lead	Pb,R	+ 51·0	+17·8
	As_2,R_5	+219·4	.....		Pb,R,aq	+ 53·4	.....
Antimony	Sb_2,R_3	+167·4	+34·0		Pb,R_2	+ 63·4	.....
	Sb_2,R_5	+228·6	.....	Copper	Cu_2,R	+ 43·8	+20·2
Bismuth	Bi_2,R_3	+137·8	.....		Cu,R	+ 40·4	+10·2
Manganese	Mn,R, aq	+ 94·8	+45·2	Tin	Sn,R,aq	+ 69·8	.....
	Mn,R_2	+116·2	.....		Sn,R_2	+135·8	.....
	Mn_3,R_4	+398·0	.....	Silver	Ag_2,R	+ 7·0	+3·0
				Gold	Au_2,R_3	+ 11·2	.....

(a) Precipitated. (b) From crystallized Si. (c) Not precipitated.

heats of formation of oxides and sulphides of the elements named. The heats expressed are in calories, obtained at a common temperature of 15°C., but the heats given are relatively true at the temperature of Bessemerizing copper matte.

The heat disengaged in the formation of silicon oxide, which amounts to 219·2 calories shows very clearly the important relation which that element bears to the working of the copper converter. Applying the figures of the table to the following reactions, are obtained:—

$$FeS+30=FeO+SO_2+114{\cdot}4 \text{ Cal.}$$
$$+23{\cdot}8 \quad +69+69{\cdot}2$$
$$CuS+30=CuO+SO_2+97{\cdot}0 \text{ Cal.}$$
$$+10{\cdot}2 \quad +38{\cdot}0+69{\cdot}2$$
$$Cu_2S+30=Cu_2O+SO_2+91 \text{ Cal.}$$
$$+20{\cdot}2 \quad +42{\cdot}0+69{\cdot}2$$

It is evident that these reactions are produced in the converter through the combinations of air and sulphur. The heats of formation of the silicides have not yet been measured, nevertheless it is easy to understand that the copper does not

[2] *Mémoirs de la Société des Ingénieurs Civils de France,* 6, 2, 1902.

slag so much while sulphur remains in the matte, for the sulphur helps the iron to transform copper oxide into sulphide at the moment it is produced, the reactions of which follow:—

$$CuO+FeS=CuS+FeO+17{\cdot}4 \text{ Cal.}$$
$$+38{\cdot}0+23{\cdot}8 \quad +10{\cdot}2+69$$
$$Cu_2O+FeS=Cu_2S+FeO+23{\cdot}4 \text{ Cal.}$$
$$+42{\cdot}0+23{\cdot}8 \quad +20{\cdot}2+69{\cdot}0$$

Passing now to the last period of the operation where the sulphide (Cu_2S) is transformed into copper, the final reaction follows:—

$$Cu_2S+20=2Cu+SO_2+49 \text{ Cal.}$$
$$+20{\cdot}2 \qquad +69{\cdot}2$$

It is strongly exothermic and it is evident that it should be produced. But it is not produced directly and it must be admitted that it is produced by reactions analogous to the English reverberatory method,

$$(1)\quad Cu_2S+2Cu_2O=3Cu_2+SO_2—35{\cdot}0 \text{ Cal.}$$
$$+20{\cdot}2+2\times42 \qquad +69{\cdot}2$$

This reaction is endothermic, which is explicable because in the English method after having permitted the material to oxidize itself it is given another heat. In the converter the mass re-heats itself at each instant by the formation of the same oxide,

$$(2)\quad Cu_2S+30=Cu_2O+SO_2+91 \text{ Cal.}$$
$$+20{\cdot}2 \qquad +42{\cdot}0+69{\cdot}2$$

Multiplying this second equation by 2 and adding it to the first we have

$$(3)\quad 3Cu_2S+2Cu_2O+60=3Cu_2+2Cu_2O+3SO_2,$$

which after simplifying the preceding equation becomes

$$Cu_2S+20=2Cu+SO_2.$$

In closing it is noted that the mass can still gain temperature by the formation of slag.

A part of the foreign metals disappears in consequence of the physical phenomenon called volatilization. The anhydrides of arsenic and antimony volatilize, the first passing into the state of vapor without decomposition at 200°C., the second decomposes to the red oxide and sublimes. With contact of air it can give the peroxide Sb_2O_6. The zinc can volatilize for the temperature of the converter is higher than 1,000°C. The vapors of zinc are oxidized and carried off. A part of the lead disappears also in the state of vapor. The temperatures of volatilization of a few metals are as follows:—

TEMPERATURE OF VOLATILIZATION OF METALS.

	Degrees Centigrade.	In Vacuum.		Degrees Centigrade.	In Vacuum.
Arsenious Acid....	200	.....	Zinc	930	184°
Antimony...	432	.....	Lead.....	(?)	360°
Cadmium.....	776	.....	Tin	(?)	360°

The Selecteur.—The preceding thermo-chemical reactions account for the elimination and selection of the foreign metals as follows: The elimination of the foreign metals is accomplished partly by scorification, and an examination of the table of heats of formation shows that nearly all the bodies which figure there in passing from the state of sulphides to that of oxides disengage more heat than copper, therefore it is concluded that they oxidize first, followed by those which scorify, *viz.:* tin, zinc, lead, antimony and manganese. Moreover the oxidation and scorification of the foreign metals is not completely attained, and they remain partially in the white metal. Their elimination proceeds during the treatment of white metal in the furnace and proportionately as the copper is rendered nascent it will precipitate them from their sulphides at least those which disengage less heat of formation than the copper by the reactions—

$$MS+2Cu=M+Cu_2S$$
$$\text{and } M_2S_3+6Cu=2M+3Cu_2S.$$

It is seen, therefore, that the sulphides of nickel, cobalt, lead, silver and antimony should be decomposed, and also that a very small portion of copper desulphurizes a large proportion of these metals. This precipitation of the foreign metals has been adapted to a number of enterprises to purify mattes from arsenic and antimony by means of iron or lead.

The Neill Process for Leaching Copper Ores.—The Neill leaching process is based on the use of sulphurous acid for the recovery of copper from the oxide and carbonate ores. These minerals are reacted upon by sulphurous acid with the formation of cuprous sulphite (Cu_2SO_3), which is not soluble in water, but is soluble in water containing sulphurous acid—that is, the leaching solution must have an excess of the acid in it over that required to produce the reaction. The copper is precipitated by driving off the excess of acid by heat. The precipitate is cupro-cuprous sulphite ($CuSO_3 \cdot Cu_2SO_3+2H_2O$) and contains 49·1% Cu. It is a heavy, crystalline compound, of dark-red color, which settles readily from the solution and can be washed by decantation, dried and reduced to metallic copper by fusion on the hearth of a reverberatory furnace. Very small amounts of other metals are dissolved and the product is very pure copper. In practice the ore is crushed to pass a 20-mesh sieve, put in covered tanks and kept in a state of agitation while a current of sulphurous acid from the generators is forced through it. The copper will pass into solution in from one to four hours. The solution is drawn off through a filter press to separate the slimes. The latter and the sands are washed once with water, which is used over with the next charge. The solution in the precipitating tank is heated with exhaust steam, precipitating the copper salt. The plant can be arranged to save nearly all the sulphurous acid except that combining with the copper. One pound of sulphur is required to convert four pounds of copper into sulphite, or, with the loss from the excess, one pound converts three pounds. The sulphurous gas can be obtained either by burning pyrite or sulphur. Roasting a copper sulphide ore to an oxide will provide ample acid for its treatment. A test on a mixture of copper carbonates and some oxide in a siliceous ore gave 95% extraction. The advantages of the process over the sulphuric or hydrochloric acid method are: (1) Cost of

the chemical is low. (2) It is generated on the spot by the use of a very simple plant. (3) A relatively small amount of the chemical is used. (4) The copper is separated from the solution by heat alone. (5) The copper produced is practically free from impurities.

Reactions of the Ziervogel Process.—Robert H. Bradford[3] discusses in detail the reactions and temperature limits of the Ziervogel process, the investigation being confirmed by various exhaustive experiments. The author finds the range of temperature necessary for the process to be between 655 and 800°C., and that care should be taken to avoid heating to 850°C. Above 655°C. the silver sulphate is in the liquid state. Copper sulphates require 700°C. for their decomposition.

Apparatus for Casting Metal.—For casting metals, J. B. F. Herreshoff has patented a device[4] consisting of the combination of a series of molds, each having a liquid-circulating system, with means for causing the said molds to travel in a closed path, a stationary platform supported within the path of travel of the molds, a water-supply pipe forming the pivot of the system of molds, located beneath the platform and in liquid-conducting communication with the liquid-circulating system of the molds, a furnace or other source of molten-metal supply, and a trolley-supported ladle arranged in operative relation with the furnace and the moving molds.

Electrolytic Copper Tubes.—During 1901 the English Electro-Metallurgical Co., which some time ago acquired the English works and patents of the Elmere copper tube process, produced an average of 25 tons of copper tubes per week. The improvement on the process by the late M. Secretan, in France, induced the owners of the French patents to acquire and operate the English patents also. The company expects to increase the output of the plant to its designed capacity of 60 tons per week as soon as it shall have been placed on the Admiralty list of contractors, the Board of Trade's requirements as to quality complied with, and the points in dispute between the vendor syndicate and the company settled.

Progress in the Electrolytic Refining of Copper in 1901.

By Titus Ulke.

Electrolytic Copper Refineries.—The subjoined carefully compiled statistical table gives the principal data required for determining the present status of the electrolytic copper refining industry in the United States. About 576 tons of electrolytic copper are produced in this country daily, or 210,240 tons annually, valued approximately at $67,768,762. The by-product recovered daily contains about 53,187 oz. silver and 501 oz. gold, which makes an annual output of 19,413,255 oz. of silver, valued at $11,444,114, and 182,865 oz. of gold, valued at $3,779,820.

During 1901, ten copper refineries were in operation in the United States. The electrolytic works at Irvington, N. J., of Glorieux & Woolsey, known as the Irvington Smelting & Refining Co., was shut down in 1900 to be dismantled, while the new plant of the De Lamar Copper Refining Works, near Cartaret, N. J., is in course of construction.

[3] A paper read before the American Institute of Mining Engineers, May, 1902.

[4] United States Patent No. 669,696, filed March 12, 1901.

The Perth Amboy plant (Guggenheim Works) of the American Smelting & Refining Co. has been enlarged so that 150 tons of electrolytic copper can be handled in it, instead of its former capacity of 50 tons. It is expected to operate only about two-thirds of the capacity, the remaining one-third being held in reserve. This will explain the surplus of generator power as compared with the actual daily output.

At the Buffalo Copper Works, about 60% of the Calumet & Hecla Co.'s enormous production of native copper concentrates is refined, the argentiferous copper material running over 20 oz. silver being melted down and cast into plates, which are sent to the electrolytic works.

ELECTROLYTIC COPPER REFINERIES IN THE UNITED STATES OPERATED IN APRIL, 1902.

No.	Name of Company and Location of Works.	Kind of Material Chiefly Treated.	Approximate Daily Copper Output in Tons (2,000 lb.)	Number and Capacity of Generators. Kw. = Kilowatts.	No. of Tanks in Refinery.	Arrangement of Electrodes.	Approximate Daily Output of Gold and Silver from Slimes.
1...	Raritan Copper Works (Lewisohn Bros.), Perth Amboy, N. J.	Converter Copper from Boston and Montana, Butte and Boston, Old Dominion, Arizona Copper Co., Copper King, Ltd., and Highland Boy	150 to 200 (Cap. 200)	Five @ 600 Kw.	1,600	Multiple.	8,000 to 10,000 oz. Ag. 175 to 200 oz. Au.
2...	Guggenheim Refinery, Perth Amboy plant of Amer. S. & R. Co., Perth Amboy, N. J.	Anodes and pig copper from Mexico and Colorado.	100 (Cap. 150)	Three @ 520 Kw.	1,250	Multiple.	25,000 oz. Ag. 200 oz. Au.
3. .	Anaconda Mining Co., Anaconda, Mont.	Anaconda anodes.	40 (Cap. 150)	Six @ 270 Kw. Two @ 360 Kw. One @ 200 Kw.	1,480	Multiple.	4,207 oz. Ag. 25 oz. Au.
4...	Baltimore Smelting & Rolling Co. (Baltimore Copper Works), Baltimore, Md.	Converter copper from Anaconda, Mt. Lyell and part of the Germania Works output.	80 (Cap. 100)	Eleven @ 80 Kw.	540	L. p. series. S. p. multi.	6,400 oz. Ag. 28 oz. Au.
5...	Boston and Montana Cons. Copper and Silver Mining Co., Great Falls, Mont.	Boston and Montana anodes and miscellaneous material.	60	Two @ 810 Kw.	600	Multiple.	3,960 oz. Ag. 9 oz. Au.
6...	Nichols Chemical Co., Laurel Hill, N. Y.	Mountain Copper and Copper Queen anodes and Canadian and Spanish pyrites cinders.	60	Four @ 200 Kw.	400	Series.	1,000 oz. Ag. 34 oz. Au.
7...	Balbach Smelting & Refining Co., Newark, N. J.	Orford anodes and miscellaneous.	45 (Cap. 50)	Eight @ 75 Kw.	432	Multiple.	3,000 oz. Ag. 15 oz. Au.
8...	De Lamar Copper Refining Works, Sawyers, N. Y.	Blister copper from Bully Hill mines, Cal.	27 (Cap. 50)	Two @ 270 Kw.	408	Multiple.	1,680 oz. Ag. 30 oz. Au.
9...	Buffalo Smelting Works, Black Rock, N. Y.	Lake Superior, argentiferous native copper "mineral."	26 (Cap. 40)	One @ 510 Kw. Two @ 48 Kw.	270 490	Multiple.	520 oz. Ag. — oz. Au.
10..	Chicago Copper Refining Co., Blue Island, Ill.	By-products and miscellaneous pig copper.	5	Two @ 64 Kw.	250	Multiple.	100 oz. Ag. 3 oz. Au.

Practically all of the silver in the crude copper passes into the slimes or tank-mud, and is periodically recovered by boiling the silver-mud with sulphuric acid

to remove the bulk of the impurities, refining it on a small furnace-hearth and casting the silver into bars weighing about 1,000 oz. each. The absence of gold from the argentiferous copper obtained by reducing the native copper ores of Michigan is remarkable and greatly simplifies the silver parting process.

The new 40-ton electrolytic copper refinery, built east of the old works, is furnished with power by a McIntosh-Seymour engine, driving a Crocker-Wheeler generator, which is guaranteed to deliver a current of 300 volts and 1,700 amperes when running at a speed of 126 revolutions per minute. There are 490 tanks in the new refinery, with a basement underneath the tank floor to facilitate inspection for leakages and emptying of the tanks. The circulation of the electrolyte is effected by a cascade arrangement of the tanks instead of on a level, as in the old refinery, the solution being pumped to the highest row of tanks. The anodes measure 29 in. long, 27 in. wide, and about 1 in. thick, and are provided with small lugs on top instead of large side lugs, which were formerly used. Electric traveling cranes and racks similar to those in use at the Perth Amboy refineries, will be used for charging the tanks with plates and removing the cathodes.

Each heat of refined copper is tested for the mechanical properties, and for the electrical conductivity of the copper as follows: Representative sample bars, weighing about one pound each, are cast at the pouring of every furnace charge. Pieces of sufficient length from these sample bars are passed through small rolls and annealed at a dull red heat in the muffle of an assay furnace whenever they become too hard. They are then pickled in dilute sulphuric acid, washed in water and passed through successive dies, finally being drawn into wire about 0·125 in. in diameter. These wires are numbered, and constitute the samples used in the Siemens' apparatus for making the conductivity tests. Good annealed copper wire 0·125 in. diameter should possess a conductivity of at least 98%, should stand about 55 twists before breaking, and should show a tensile strength of not less than 24 tons per sq. in. of cross section, according to the usual standard.

The cost of electrolytic refining at the Buffalo works I estimate not to exceed 0·3c. per lb. of crude copper, with current delivered at a cost of $27 per H.P. per year.

Cowper-Coles Centrifugal Copper Process.—S. O. Cowper[1] covers an improvement in the process of electro-deposition on rapidly rotating mandrels, by projecting the electrolyte tangentially against the mandrels. He claims the deposition of copper absolutely free from lamination at the high rate of 200 amperes per sq. ft. of cathode surface, in making 12-in. diameter tubes, the gas bubbles or suspended impurities being thrown off by centrifugal force. The cathode is rotated at a speed up to 1,000 revolutions per minute, and a current density of 170 amperes per sq. ft. cathode surface is preferably employed. The electrolyte is preferably kept at a temperature of 160°F.

The following advantages are claimed by Cowper-Coles for his process: 1. Rapidity of action five times as great as the ordinary electrolytic processes. 2. Less plant and floor space. 3. Cheaper. 4. Sheets and tubes free from lamination. 5. Less waste of copper and high grade of product.

[1] British Patent No. 9,731, of 1901.

This process certainly appears to lack novelty, for the reasons given in THE MINERAL INDUSTRY, Vol. IX., page 229. The apparatus, moreover, in its present shape, as disclosed in the patents is too complicated and is in other respects not fully suited to the electrolytic refining of argentiferous copper commercially.

The apparatus employed for the centrifugal process[2] consists of a wooden vat in which are placed crude copper anodes; the cathode is a hollow brass mandrel supported on a revolving shaft, the latter being brought through the bottom of the vat to the top, and protected from the copper sulphate solution by a lead-cased cast-iron column. The shaft is revolved by gearing placed beneath the depositing cell, the speed varying with the size of the mandrel employed. The mandrel at one end is fitted with an eye bolt with which to lift it, and a circular brass casting against which the contact brushes rub for collecting the negative current. The brushes are fitted to arms which are made to turn backward to allow of the easy insertion and withdrawal of the mandrel. To prevent the electrolyte being carried round with the mandrel it is found necessary to have baffle plates made of insulating material. A baffle plate is also placed at the bottom of the mandrel to prevent the formation of copper trees or nodules. The electrolyte is briskly circulated through the cells by means of an acid proof pump, the solution being forced or pumped into a reservoir, where it passes through a filter to rid it of all suspended impurities. When it is desired to obtain a sheet of copper, the tube after being removed from the mandrel is cut, flattened out and annealed, while for wire, a piece of insulating material is wound round the mandrel in the form of a spiral and the copper deposited between the threads until its thickness is about equal to the distance between the threads. The spiral of deposited copper is then removed and, after annealing, is drawn down in the usual manner.

Keith's Electrolytic Process of Recovering Copper.—Dr. N. S. Keith's process, as carried out recently at Arlington, N. J., on ore containing from 1·5 to 2% Cu, is essentially one of crushing, roasting, leaching and electrolization, the copper being finally deposited on the cathodes in the electrolytic tanks.

The special feature in this process lies in the peculiar arrangement of the electrodes so as to prevent the deposition of spongy copper by insuring a retrogressive decrease of current density at the electrodes of each tank after the first, the number of electrodes per tank being increased progressively from the first to the last tank of the series employed. In this way the amperes of current flowing through each tank, which is connected in series circuit with the one adjoining, is kept the same, while the current density at the electrodes, which are connected in multiple in each tank, is decreased from the first to the last of the series of tanks, to compensate for the decrease of copper in the electrolyte in its course through them. Thus the current density may be from 15 to 20 amperes per sq. ft. of cathode surface with a 6% Cu solution, and 3 amperes per sq. ft. with a 0·5% Cu solution, provided a sufficiently rapid circulation of the electrolyte be maintained. The density of current in each tank must not exceed the limit required for the deposition of reguline copper.

Electrolytic Production of Cathode Plates.—E. G. Elliott and V. Kishner,

[2] Private communication from Mr. Cowper-Coles.

Perth Amboy, N. J., patented[3] a metallic cathode for receiving movable sheet-metal deposits upon both of its sides throughout its immersed surface, said plate being partially immersed in an electrolytic solution from which the metal may be deposited from a suitable anode, and with a scratch-groove upon its exterior, whereby the metal electro-deposited is rendered separable along the line of the groove during deposit.

Forms of Cathode Plates.—W. A. McCoy, of Perth Amboy, N. J., secured a patent[4] for an improved form of cathode plate, the object of which is to avoid the expense of the wooden cathode-frames heretofore commonly used on cathode plates to prevent the metal deposited upon one side of the cathode from becoming inseparably connected with the deposit upon the opposite side. At or near the lateral edges and bottom to facilitate stripping at opposite sides of the plate, are a series of recesses in the face of the plate, which form receptacles for any suitable insulating or non-conducting material. These recesses or receptacles are preferably perforations extending through the plate from side to side, and separate and apart from one another so that the insulating material will remain therein with security and not be detached under the rough treatment to which the more or less heavy plates are subjected when they are handled. The perforations are quite close together, so that the exposed metal between them will form but very slight connections of the deposited sheet with the metal deposited at the outside of the series of perforations, and thus the deposited sheets may be easily stripped from the cathode-plate, the sheet being easily torn or severed from the edge of metal in the act of stripping. The edge-deposited pieces may be easily removed from the cathode-plate after stripping and used as scrap metal. In practice the holes are usually drilled 0·25 in. in diameter and 0·2509 in. ($\frac{81}{1\,0}$ in.) from center to center. The insulating compound may be of any insulating material capable of withstanding the action of the electrolyte. The recesses at the sides and bottom of the plates may be continuous.

Casting Machines and Conveyors.—At the Raritan Copper Works, the anode casting machines are provided with a knocker wheel, which actuates upon a pin and thereby lifts the anode plate, weighing about 400 lb. from the mold. The wire-bar molds are ingeniously dried by jets of air issuing under 3 or 4 lb. pressure against the surface of the molds.

Walker casting machines are now being constructed so as to allow of being operated electrically instead of hydraulically or by compressed air.

In addition to the McCoy wire bar and the Walker ingot and anode casting machines, which have both been well illustrated and described in THE MINERAL INDUSTRY, Vols. VII. and IX., the Dyblie wire bar casting machine needs to be briefly noted. This machine is the invention of J. A. Dyblie, of the Illinois Steel Co., and was installed in the Anaconda, Mont., smelting plant some time since. The molds reciprocate on tracks over the tank, being overturned by means of a hand wheel to discharge the castings into the water. The overturning of one mold brings the next up into pouring position. Each end of the tilting furnace has its casting machine and tank, one ladle supplying each machine in turn. The castings are removed from the tank by means of an endless chain conveyor

[3] United States Patent No. 662,378, of Oct. 12 1901. [4] United States Patent No. 684,271 1901.

working in it. It is reported that castings made by this machine from the tilting furnace are free from pin holes and seams, and that the time occupied, and the men employed are about one-half of former hand ladling practice.

The Formation of "Trees" and "Nodules" in Electrodeposition.—Mr. J. W. Swan has found that regularity and smoothness of deposit were almost entirely dependent on the absence of solid particles held in suspension in the electrolyte, and that excrescences could be entirely avoided by freeing the electrolyte from floating particles. It has been observed that each nodule was formed around a speck of some foreign substance.

Corrosion in Depositing Copper.—H. Sayer and F. S. Spiers[5] define corrosion as meaning the dissolving away of the copper, both anodes and cathodes, on account of the ordinary chemical action (really "local" action) between it and the electrolyte, and quite apart from the action of the current itself. The gradual effect of this corrosive action is to supersaturate the electrolyte with copper and thus cause copper sulphate crystals to separate out—a consummation most earnestly to be avoided. The superfluous copper is usually removed by electrolyzing with lead anodes.

It is a disputed point whether an acid solution of copper sulphate really does dissolve pure copper without the presence of air. Schuster's experiments[6] certainly point to the fact that nearly the whole of the corrosive action is due to the presence of oxygen in the solution—thus,

$$Cu+H_2SO_4+O_2=CuSO_4+H_2O_2;$$

but Foerster and Seidel[7] categorically deny this, and declare that copper is soluble in copper sulphate even without the presence of air, the solubility increasing with the concentration. Copper, however, is quite insoluble in normal sulphuric acid at 100°C. It is probable that the prime action of the copper is to reduce some of the cupric to cuprous solution, and that this latter is subsequently oxidized by the air to the cupric form. The matter bears so far on practice that in many processes the electrolyte is either violently agitated or else air is forced through it; in such cases the corrosion of the cathode is doubtless higher than if the solution were at rest. In the case of the impure anodes, corrosion takes place even without the presence of air and corrosion of cathodic copper may take place indirectly under certain conditions—namely, in cases where cuprous oxide is deposited with the metal and dissolved in the electrolyte, forming a cuprous solution which may eventually be oxidized to cupric sulphate.

T. Gray, in his paper, "The Application of Electrolysis to the Standardizing of Electric Meters," has carefully studied the corrosion of electrolytic copper under various conditions of acidity, temperature, etc., for the purpose of determining to what extent the variations of the apparent electro-chemical equivalent of copper are due merely to the metal being redissolved. He found that the losses were very variable and indefinite, but seldom exceeded 0·000005 g. per sq. cm. per hour.

As would be expected, the values decrease with rise of temperature, and with

[5] *Electrochemist and Metallurgist*, April, 1902, p. 103.
[6] *Proceedings of the Royal Society*, 1894.
[7] *Zeitschrift fuer Anorganische Chemie*, 1897, XIV., p. 106.

diminishing current densities. Experiments indicate that while corrosion at ordinary temperatures is almost negligible, it increases as the temperature rises. The corrosion varies with acidity, but on the whole, the variations are not very considerable; however, at 50% acidity, and at a temperature of 80°C., the copper begins to be very rapidly attacked. The increase of weight in the neutral solution at 80°C. is due to the formation of a film of cuprous oxide, Cu_2O.

Arrangement of Plant.—A. L. Walker has obtained a patent[9] for a plant for electro-deposition of metals, especially copper. It specifies a plant for the deposition of metal electrically by means of heavy currents distributed through numbers of plates arranged in multiple in tanks arranged in series, embodying tanks arranged with the proximate walls substantially parallel and close together; leading-in and leading-out mains extending to the end tanks of series, said mains being of large and sufficient cross-section to carry the entire current supplied to all the tanks, distributing-bars of small cross-sectional area supported between adjacent tanks, and anodes and cathodes arranged in the tanks and having supporting projections at the top, the supporting projections of the anodes and of the cathodes in adjacent tanks resting freely on the same distributing bars whereby electrical connection between anodes and cathodes of adjacent tanks is established through connections individually of small and insufficient area to carry the total current but collectively of an area sufficient to carry said current, the supporting projections at one side of the anodes of the first tank and of the cathodes of the last tank resting freely on the leading-in and leading-out mains respectively.

The De Lamar plant, near Cartaret, N. J., has agreed to pay a royalty for the use of this arrangement in its electrolytic department.

Electrolytic Process of Making Copper Sulphate.—H. Palas and F. Cotta, Marseilles, France, obtained a patent[10] for the process of producing metallic sulphates and simultaneously obtaining an alkaline base as a by-product by electrolysis, said process consisting in separating the anode and cathode by a porous diaphragm, supplying a stream of the electrolyte solution of an alkali-metal sulphate to a soluble anode of the metal to be transformed into sulphate, supplying another stream of the same electrolyte solution to the cathode on the other side of the diaphragm and passing a current of electricity through the apparatus. In particular, a cathode of iron or other metal not attacked by alkalies, is surrounded with an electrolyte of sodium or potassium sulphate. In the anode compartment is an anode of the metal to be converted, surrounded with an electrolyte of its sulphate, *e.g.*, a copper anode in a solution of copper sulphate. The strengths and temperatures of the electrolytes should be such as to afford the least electrical resistance. On passing a current of 2·5 to 3 volts, the SO_4 ion from the sodium or potassium sulphate passes to the anode side, and meeting the free copper re-forms copper sulphate. The SO_4 ion freed from the copper sulphate attacks the anode, and so strengthens the anode electrolyte. Eventually a solution of caustic soda or potash is left in the cathode cell, and an enriched solution of copper sulphate, entirely free from alkaline sulphate, is obtained in the anode cell.

[9] United States Patent No. 687,800, Dec. 3, 1901.

[10] United States Patent No. 679,985, 1901.

On the Crystallization of Copper Sulphate.—In a series of experiments on the crystallization of copper sulphate, Arthur J. Hopkins[11] found that the size of the crystals was not dependent on the degree of concentration, nor on the relation of the size of the crystallizing vessel to the volume of the contained solution nor finally on the rapidity of cooling. In a solution supersaturated in absolute quiet, no crystals will form. Solutions of convenient concentration and volume were obtained when 171 g. copper sulphate crystals were dissolved in water and 15 c.c. normal sulphuric acid were added, the whole being concentrated to less than 340 c.c. and later diluted to exactly that amount with boiling water. The size of the crystals desirable for quantitative work was decided to be of a length of from 20 to 30 mm. and as the ratio of the volume of the solution to the horizontal surface of the containing crystallizing dish is identical with the depth of the solution for each volume, a dish was selected which would give a constant depth. A depth of 6 mm. was found to allow ample space between crystals 20 to 30 mm. long when crystallized from a solution of the strength indicated above. The diameter of the dish which will hold 340 cm. at a depth of 6 mm. is 26 cm. and, in general, for this depth, the diameter required is the square root of twice the contained volume. Under these conditions, the size of the crystals will depend upon the number of crystal points first started in the solution, as it cools beyond the saturation point. The number of these points depends upon the conditions obtained in the dish during the time of supersaturation, and they are formed by allowing a slight blast of cold air to impinge on the surface of the cooling solution, which operation is continued until the proper number has been obtained. Very little practice enables one to ascertain this condition from the spacing between the floating crystals rather than the actual number of them. For crystals of a different size a few tests will determine the proper spacing as well as the proper size of the crystallizing dish. In the opinion of Mr. Hopkins, crystals of any desired size may be obtained not only from the original solution but from all successive mother liquors.

Use of Magnesium-Copper Alloys in Casting Copper.[12]—Among the means commonly employed in casting to free copper from dissolved gases and cuprous oxide, magnesium occupies a prominent place. Its action is to unite with the free oxygen and the oxygen combined in SO_2, CO and Cu_2O to form MgO, which yields a slag covering the molten copper. The slag is then skimmed off and the copper poured which gives a dense casting free from blowholes. The use of metallic magnesium for this purpose requires skill and care in order to avoid the violent sputtering of the molten copper, which might cause injury to the workmen. This disadvantage may be entirely obviated by introducing the magnesium in the form of an alloy with copper, such as the cheap 50 Copper-50 Magnesium alloy now produced in large quantities at Hemelingen, Germany. This alloy is reddish-gray in color and stellate in structure upon fracture. Its sp. gr. is 2·97, and it melts at 450°C. It is very brittle and may therefore be broken easily with a hammer into conveniently sized pieces. In most cases not more than 50 g. of the magnesium alloy is required to make a dense casting of 100 kg. of copper, but in practice it is best to add the alloy in portions of 20 g. until the desired action

[11] *American Chemical Journal*, May, 1901. [12] *Chemiker Zeitung*, 1901, Report 186.

is secured. Higher proportions of the alloy than those stated increase the hardness and consequently the resistance of the copper and may be used in improving the quality of brass, bronze, and similar alloys.

Copper Wire for Power Transmission Lines.—Dr. Bell[13] states: "At present the best grades of standard copper wire have a conductivity of fully 98% that of the chemically pure metal, and even this figure is frequently exceeded. On account of the comparatively low tensile strength of copper—ordinarily about 35,000 lb. per sq. in.—efforts have been made to exploit various alloys of copper on the theory that their greater strength would more than counterbalance the lessened conductivity and increased cost, by enabling less frequent supports to be used. Aluminum bronze, silicon bronze and phosphor bronze have been tried, together with some other alloys of a similar nature. . . . Copper which is hard-drawn has a greater tensile strength than any so-called bronze of similar conductivity—from 60,000 to 70,000 lb. per sq. in.—with a resistance less than 5% in excess of that of ordinary copper. The following table gives the conductivities and tensile strengths of some of the various materials used or proposed for live wires, pure copper being taken as the standard at 100% conductivity.

Material.	Conductivity.	Tensile Strength. Pounds.
Commercial copper wire	98 to 99	35,000
Good hard-drawn copper	96 to 97	60,000 to 65,000
No. 1. Silicon bronze	97	63,200
No. 2. Silicon bronze	80	76,000
No. 3. Silicon bronze	45	110,000
Phosphor bronze	26	101,000
Iron annealed wire	14	55,000
High carbon steel wire	10 to 12	120,000 to 130,000

"It is evident that where the best combination of strength and conductivity is wanted, hard-drawn copper wire is unexcelled. For all ordinary line work good annealed copper wire is amply strong; it is, besides, easier to manipulate than wire of greater hardness. Occasionally, where it is desirable to use extra long spans, or excessive wind pressure is to be encountered, the hard-drawn wire is preferable."

Manufacture and Use of Silicon-Copper.—The Cowles Electric Smelting & Aluminum Co., Lockport, N. Y., makes silicon-copper in the electric furnace, and claims to be the only maker of pure silicon-copper, also that the metal made by the Waldo Foundry Co. and the John A. Roebling's Sons Co. is more properly silicon-bronze, made by adding silicon-copper to pure copper.

O. J. Steinhart, however, affirms that copper silicide is being produced by the Fabrik Electrometallurgischer Produkte, at Frankfort-on-Main, Germany, with 10%, 15% and 30 to 35% Si in the shape of ingots weighing from 15 to 18 lb., which are divided by notches, so that they can be easily broken into smaller pieces.

Among the uses for copper silicide are: 1. In place of copper phosphide as a purifying and deoxidizing agent, acting as a reducing medium should any of the oxygen compounds of arsenic and antimony be present, and thereby counteracting their deleterious effects. The resultant metals combine with the metallic copper, whereas the silicon employed does not enter into combination with it.

[13] *Electric Transmission of Power*, pp. 362-373.

If copper is therefore finally refined with copper silicide, a greater strength and toughness is imparted to it.

2. Silicon may also be added to copper in such a manner that it forms a permanent compound with the latter, thereby adding materially to its hardness and strength, which can be made equal to that of steel if a sufficiency of silicon is incorporated with it. Small quantities up to about 0·1% render it particularly suited for telephone wires, and other electrical purposes, as this alloy possesses a far greater strength than ordinary electrolytic copper wires.

The subjoined table gives figures showing the relative conductivity and tensile strength of pure copper and these alloys:—

Material.	Tensile Strength, per sq. mm. in kg.	Conductivity.
Pure copper wire	28–35	100
Cu with 0·02 to 0·05% Si	45	98
Cu with 0·05, 1·1% Si and 1·1% Sn	88	43
Cu with 0·5% Si	50	98
Cu with 3·5% Si	95	7

These alloys are particularly suited for bolts in locomotive fire-boxes, for rivets, wire ropes, etc.; that is, in all cases where high tensile strength and small elongation are required and iron is not admissible, as well as those in which an acid-resisting material should be employed.

3. Copper silicide forms a very useful addition to tin and zinc bronzes in place of copper-phosphide. The bronzes thus prepared are very elastic and heat resisting, much less silicide being required as compared with the corresponding phosphorus compound. The purifying power of 10% silicide as compared to the same strength phosphide is as 1·48 : 1, or entails a saving of about half the material when the former is employed.

4. As an addition to aluminum bronzes it should be of great importance, as alloys can be obtained with high tensile strength, ranging with respect to their hardness from ordinary brass to the hardest phosphor bronze. The manufacturer, therefore, has a very convenient means of preparing his alloys for any specific purpose. If, for instance, aluminum bronze of great strength is required, being soft at the same time, the chilling of the alloy when red hot is advisable. Generally speaking, the presence of silicon in aluminum bronzes, such as the Heroult and Cowles bronzes, increases their strength and hardness, and at the same time reduces their elongation.

With reference to the quantity of copper silicide required for these various purposes an exact rule cannot be laid down, as this depends upon the object to be attained and the material employed, but in most cases from 50 to 100 g. per 100 kg. will generally suffice for copper alloys and bronzes.

Determination of Oxygen in Commercial Copper.—Maurice Lucas[14] states that oxygen is generally estimated in copper by two methods, *viz.*, reduction by hydrogen and measuring the loss of weight, which represents the oxygen and the volatile metals; or by treatment with silver nitrate and estimation of the copper in the residue. A third method has been devised which consists in melting the copper with tin in the electric furnace in a current of carbon monoxide; the

[14] *Bulletin Société Chemie*, 23 (24), 900–904.

carbonic acid formed is then collected and weighed. The copper and the quantity of pure tin necessary to form a 20% alloy are placed in a tared porcelain boat in the cool part of a porcelain tube, and the CO gas passed over it for 15 minutes; the potash and sulphuric acid bulbs, previously weighed full of air, are then attached to the tube. The latter is then gradually moved until the boat is in the hot part and the temperature is maintained at 900°C. for an hour. The bulbs are then disconnected and weighed again full of air. The boat is allowed to cool by moving the porcelain tube back to its original position, and the boat is finally weighed. In this manner is obtained first, the weight of CO_2 formed, which multiplied by 0·364 gives the oxygen set free, and secondly, the loss of weight, which represents the oxygen and the volatile bodies, as arsenic, antimony, etc.

This method has been satisfactorily tested with pure cuprous oxide and with known mixtures of cuprous oxide, copper and tin. The effect of impurities was also determined by adding a mixture of copper arsenate, phosphate, etc., to the pure copper and tin in the boat. The method is said to be applicable to all metals whose oxides are reducible by CO.

The Cyanide-Assay for Copper.—H. H. Miller, in a paper read before the American Institute of Mining Engineers, November, 1901, states essentially that the amount of KCN necessary to decolorize a copper solution does not give the true amount of copper present in the ore or matter when these contain other bases which interfere with the assay. When the acid solution is precipitated with excess of ammonia, Ag, Ni, and Zn, if present in the ore, go into the solution, and react like copper with the KCN; while Fe, Mn and Al are precipitated as hydroxides. This precipitate invariably contains a small portion of the copper which, in the case of iron, is probably mechanically retained; but where manganese is present there is a further retention, possibly as a manganate. Arsenic may also form an insoluble arsenate; and Cr also interferes. Miller found that the amount of copper retained by these causes combined varied indirectly as the ratio of the total copper to the disturbing elements present.

In standardizing the KCN solution for any particular ore or class of ores of the same composition, two portions of 10 g. each are weighed out for separate assays. To one is added a weighed amount of pure copper, and the two are run through together, being treated in all respects like regular assays. The difference in the number of c.c. of KCN used in the two assays represents an amount equivalent to the weighed excess of copper taken, and from this the true value of the ore is readily ascertained. Operating on the same weight of identical gangues, this figure (with frequent checking) is used. For a different gangue, or a different weight of the same gangue, another test must be made; and whenever an accurate determination of a new ore is required, the assay is run in duplicate as above described.

If due attention be paid to the above details the cyanide method will prove superior to the iodide volumetric method. The latter is certainly no quicker, and consumes much larger quantities of chemicals, besides being subject to many sources of error. The colorimetric assay, an improved application of which has been described by Mr. J. D. Audley Smith,[15] is adapted to low-grade ores

[15] *Transactions of the American Institute of Mining Engineers*, Vol. XXX., 857.

only, and for these does not seem to possess any advantages over the cyanide method, either in point of time or accuracy of results.

By effecting the solution in acid on a thick asbestos pad, heated by gas- or gasoline-burners, a number of assays can be made at once, requiring little or no attention from the time they are placed on the fire until they are ready for the addition of ammonia. The mixed acid and dilute ammonia is kept prepared in qauntity. For measuring out the portions of acid and ammonia for each assay, the most convenient vessel is a graduated cylinder of 100 c.c. capacity.

The cyanide method can be applied with equal success to richer ores, as well as to concentrates and mattes. For low-grade ores containing not over 1% Cu, the KCN solution should not be stronger than 1 c.c. = 0·005 g. Cu. For richer material a solution of twice this strength can be used to advantage.

Determination of Copper by Precipitation with Aluminum and Electrolysis.—The following quick and exact method for the quantitative estimation of copper in pyrites, impure matte, etc., is described by O. N. Heidenreich.[16] From 2 to 5 g. of the pyrites or similar substance, is dissolved in aqua regia, the nitric acid evaporated off, and the residue redissolved in 5 c.c. dilute hydrochloric acid and 10 c.c. water. The whole is washed into an Erlenmeyer flask, diluted to 100 c.c., and warmed with excess of sheet aluminum on the sand-bath. When the solution is colorless, showing that all the iron oxide is reduced, the solution is filtered, and the residue (copper and aluminum) is washed free of chlorine, the filter-paper burned, and the copper and aluminum dissolved in nitric acid. The copper solution thus obtained is finally subjected to the ordinary electrolytic assay.

The Ferrocyanide Assay for Copper.—F. Repiton[17] describes a method which is essentially as follows:—

To the neutral boiling sulphate solution to be assayed is added a decinormal solution of potassium ferrocyanide, until the characteristic blue end reaction is obtained with a few drops of a decinormal solution of iron sulphate, placed on a porcelain surface.

One c.c. N/10 potassium ferrocyanide=0·0063 g. Cu, according to the equation:—

$$K_4Fe(CN)_6+2CuSO_4=Cu_2Fe(CN)_6+2K_2SO_4.$$

Electrolytic Silver Refining. The electrolytic silver refineries in operation in the United States in 1901 are given in the subjoined table:—

ELECTROLYTIC SILVER REFINERIES OPERATED IN 1901.

No.	Name of Company and Location of Works.	Material Treated.	Estimated Daily Output.	Estimated Daily Capacity of Plant.	No. Tanks.	No. and Capacity of Generators.
1...	American Smelting and Refining Co., Perth Amboy, N. J.	Doré bullion from lead and copper refinery.	75,000 oz. Troy.	100,000 oz. Troy.	120	One, 62 Kw.
2...	Balbach Smelting and Refining Co., Newark, N. J.	Doré bullion from lead and copper refinery.	30,000 oz. Troy.	30,000 oz. Troy.	48	One, 40 Kw.
3...	Globe Smelting and Refining Co., Denver, Colo.	Doré bullion from lead refinery and miscellaneous sources.	20,000 oz. Troy.	33,000 oz. Troy.	48	One, 40 Kw.

[16] *Zeitschrift fuer Analytische Chemie*, XL., 15; also, *Zeitschrift fuer Elektrochemie*, Reportorium.
[17] *Moniteur Scientifique*, 1902, 4, Ser. 16, 287.

No gold bullion was electrolytically refined at the new mint at Philadelphia in 1901.

Treatment of Slimes from the Electrolytic Refining of Copper.

By Robert L. Whitehead.

The slimes produced in the electrolytic refining of copper vary in precious metal content from 15,000 to 22,000 oz. silver and from 4 to 200 oz. gold per ton, the copper contained being from 10 to 40%, in the form of metal, copper oxide, copper sulphide and copper sulphate, the last-named combination being due to imperfect washing of the slimes.

The usual treatment of slimes in large smelting and refining works equipped with a desilverizing department is to add the dried slimes in paper bags of 10 or 15 lb. capacity to the charge of retort metal on the cupel hearth. The copper and impurites are oxidized and pass off in the slag, while the gold and silver is absorbed in the refined retort metal remaining on the cupel. The copper dross is treated in a shaft furnace for the recovery of the copper, antimony and lead, the copper being regained as copper matte.

In electrolytic copper refineries the slimes are treated by the sulphuric acid method, which is modified according to the character of the material. In ordinary practice, the wet slimes from the tank-room are dried in a centrifugal dryer having 30-mesh phosphorbronze screens in place of the usual filter cloth. The coarse particles of copper are caught on the screen, while the slimes pass through into a storage tank. In this treatment about 10% by weight of the slimes is separated as metallic copper very rich in silver which is added to the charge in the anode furnace. The slimes after settling are transferred to a large tank lined with 12-lb. lead and equipped with two steam coils extending its full length. Hot air is forced into the solution by an injector. Sulphuric acid in the proportion of 1,500 lb. of acid (66°B.) per ton of slimes is then added and the solution boiled from 10 to 12 hours, which results in the dissolving of most of the copper, 66% of the arsenic and all of the bismuth and iron. The supply of steam is then shut off and the solution allowed to settle. The supernatant liquor very rich in impurities is siphoned into storage tanks and subsequently transferred to the evaporators for the manufacture of copper sulphate crystals (blue stone). The tank is then filled with water up to the level of the original sulphuric acid solution, the steam is turned on and the temperature again raised to the boiling point. When this is done an addition is made of the settlings from the acid parting kettles which consist of metallic copper and considerable silver sulphate. The contents of the tank are then thoroughly mixed, the copper precipitates metallic silver from the silver sulphate solution being itself transformed to copper sulphate. The treatment continues until metallic silver is no longer produced. Should the silver sulphate be in excess of the corresponding quantity of copper needed to precipitate its silver content, a small addition of untreated slimes is made to supply the deficiency. The slimes are then washed several times by decantation, transferred to filters, and washed with boiling hot water. They are then transferred to cast-iron drying pans and dried in a furnace, the dried product being subsequently mixed with sand and soda ash and melted in a

reverberatory furnace capable of holding from 50,000 to 60,000 oz. of silver. The doré bars resulting from the furnace treatment assay from 950 to 960 fine in silver and from 10 to 20 in gold, the remainder being copper. The slag from the furnace melting contains 5 or 6% copper and 3 or 4 oz. silver per ton, the quantity produced depending upon the richness of the slimes. If the slimes are very rich the quantity of slag need not exceed 200 lb. per ton of slimes treated. The doré bars are placed in cast-iron kettles and parted by sulphuric acid (66°B.), similarly to the process in use at the New York assay office and at other Government refineries.

The cement silver is thoroughly washed with hot water, placed in a hydraulic press and pressed into cakes of 1,500 to 2,000 oz. weight which are removed from the press and charged without drying into a cupel furnace of 60,000 oz. capacity. A small quantity of niter is thrown on the metal to remove the tellurium contained in the silver. When this is accomplished the molten refined silver is cast into 1,200 oz.-molds. The refined metal varies from 998 to 998·5 in fineness.

The gold is transferred to small parting kettles and boiled with sulphuric acid (66°B.) to dissolve the remaining silver. When this is accomplished a few lumps of saltpeter are added to the solution and the boiling continued for two or three hours, to remove the small quantity of silver still contained in the gold and to coagulate the finely dissolved gold which is of advantage in diminishing the quantity of float gold produced in the subsequent washing. The gold is then dried, melted under borax and cast into bars of 993 to 996 fineness.

Generally in electrolytic copper refineries, the copper sulphate solution formed by the reduction of the silver sulphates is added to the copper electrolyte in order to utilize the free sulphuric acid which is present to the extent of from 8 to 10%. The impure solution from the slimes tank is concentrated by evaporation to 42°B. and crystallized, the crystals formed being purified by repeated solution and crystallization until of marketable purity. The mother liquor from the crystals contains about 40% sulphuric acid, which is utilized by heating in a lead pan to 60°B. and subsequent cooling in iron pans. During the cooling iron and copper are separated. The resultant acid solution is used either in parting the doré bars or in the first treatment of the slimes. The slags produced in refining the slimes are treated in several ways: 1. By addition to the slags from the anode furnace, which however has the objection that the resultant copper is very impure and must be separately treated in the tank-room. 2. By treatment in a shaft furnace with litharge which yields a copper matte and a silver-lead bullion. The latter is cupelled for silver, the litharge formed being used to treat another lot of slimes slag. 3. By mixing with soda ash and melting in a reverberatory furnace which yields a very clean slag and a very base bullion. This slag is sold to lead smelters as it contains less than 60 oz. silver per ton and practically all of the antimony and tellurium of the original slimes. The base bullion is treated by adding small quantities to the regular charge of the softening furnace. The last-named method is the one used at the present time by the Seattle Smelting & Refining Co., at Seattle, Wash., in the treatment of the slimes produced by the Amalgamated Copper Co.'s plants at Great Falls and at Anaconda, Mont.

PROGRESS IN 1900 AND 1901 IN THE MAKING OF BLUE VITRIOL BY HOFMANN'S METHOD.[1]

BY OTTOKAR HOFMANN.

THE original experimental plant that was constructed for the American Smelting & Refining Co., at Argentine, Kan., for the manufacture of blue vitriol has been repeatedly enlarged during the past few years until its present capacity is 60 tons per day, which makes it probably the largest blue vitriol plant in the world. The process has been modified and improved as experience has directed and the present paper gives the progress that has been made both in construction of the apparatus and in handling the material.

The material delivered to the blue vitriol section of the works for treatment consists almost entirely of leady copper matte as the process recovers the lead which is not the case when the matte is used to make copper anodes. The matte containing about 40% Cu and from 12 to 14% Pb is pulverized through a 50-mesh screen in a Krupp ball mill of 100 tons daily capacity and the fine product is roasted in 3 two-story Pearce turret furnaces, each provided with three fire-places at the lower and two at the upper hearths. The newly constructed furnace, which is 40 ft. in diameter, has a larger capacity than either of the older ones, and the feeding of the matte as well as the filling of the coal hoppers over each fire box is accomplished by mechanical contrivances. Slack coal is used as fuel and is burned on step grates. Great care is exercised in roasting the pulverized matte, both to avoid the formation of hard lumps which easily occurs with leady matte if the temperature is not well regulated in the beginning of the roasting process, and to prepare the matte properly for the subsequent treatment with diluted sulphuric acid. These conditions call for the conversion of as much as possible of the copper into oxide and sulphate, while the iron should be changed to red oxide which is only slightly soluble in hot diluted acid. The three furnaces are discharged into a common conveyor having a water-cooled bottom. The cooled material is passed through a ball mill to reduce it a second time to the fineness of a 50-mesh screen and the recrushed material is conveyed to storage bins. The dissolving is done in eight agitating or stir tanks which are arranged in two parallel rows with a track between for the delivery of the matte. The cross section of a tank 12 ft. in diameter and 6 ft. deep is shown in Fig. 1. The bottom and sides are lined with boards for protection against wear from the friction of the pulp. In the center is suspended a heavy wooden shaft having fastened to the lower end by heavy brass plates, a cross-beam cut at both ends like a propeller-blade. In the center and fastened to the bottom of the tank is a cone-shaped projection constructed of strong wooden staves, the interior of which is filled with sand. This cone forces the matte toward the periphery, where it is subjected to the swift rotating motion of the liquor, thus preventing its accumulation in the central part where the motion is much less. Two outlet pipes provided with hard lead valves connect with the pressure tank. These are placed one above the other to permit

[1] This article is supplementary to Mr. Hofmann's monograph published in THE MINERAL INDUSTRY, Vol. VIII., under the title "Hofmann's Method for the Manufacture of Blue Vitriol." Patents for his process have been obtained for the United States, France, Spain, the United Kingdom, and Mexico.

the withdrawal of a portion of the liquor if desired, in which case the paddle is stopped and the residues allowed to settle. In the usual working of the tank, however, the lower outlet pipe only is used. The wooden ring attached to the

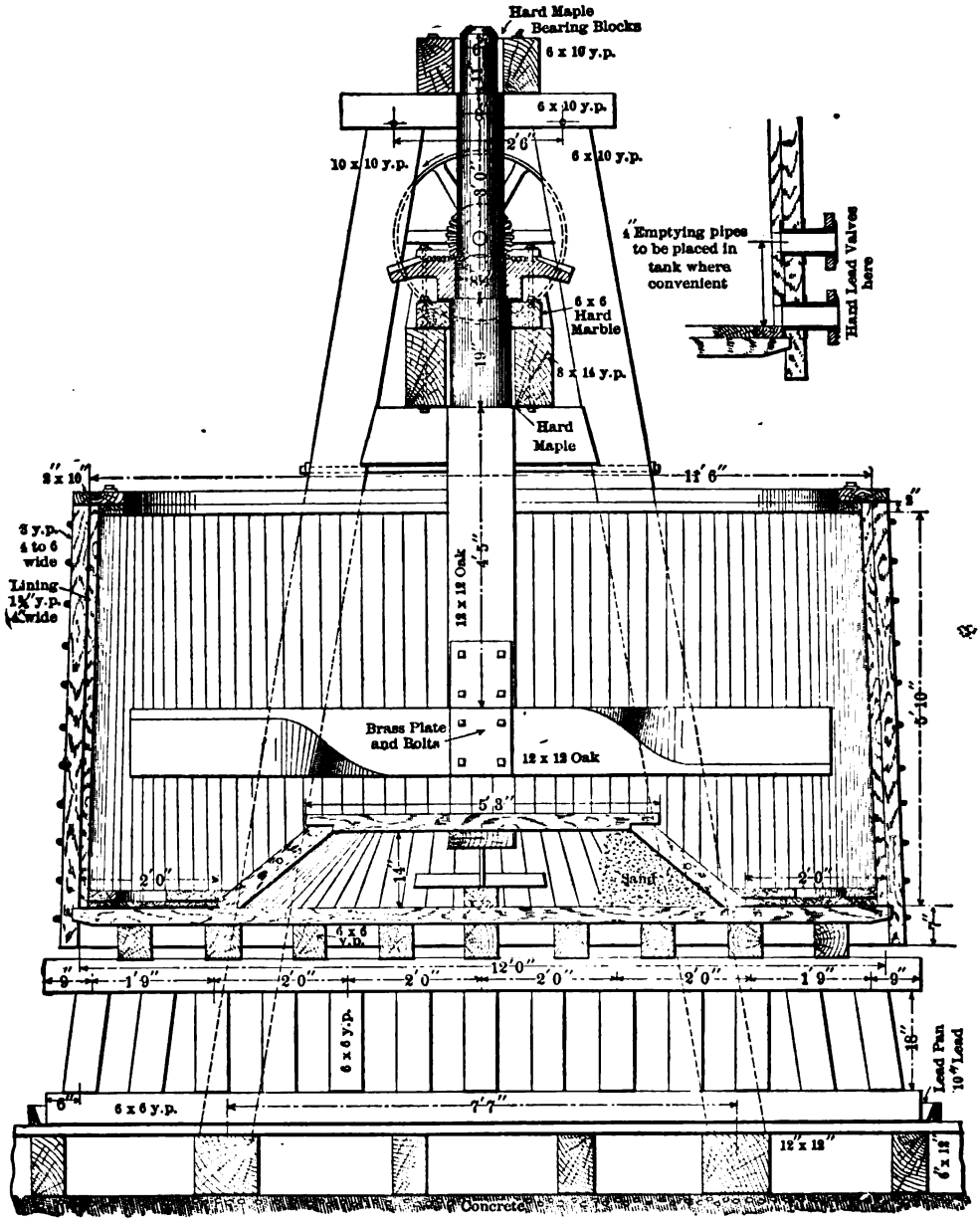


FIG. 1 STIR TANK ELEVATION AND SECTION.

rim of the tank prevents the splashing of the pulp. The tank and trestle-support are enclosed in a flat lead pan to collect any leakage. The upper end of the shaft is provided with a gear wheel to receive the power. In

charging, the stir tank is filled with water, the agitator set in motion, and the acid added, followed by matte, until the solution finally becomes neutral. The acid is conveyed to the tanks by a lead pipe which leads from the acid storage tanks. The matte is conveyed by a special car, the box of which is partly covered having a slot at the dumping end for the gradual feeding of the material when the box is brought to an inclined position. During the process the charge is heated by a jet of steam.

Below the stir tanks are two cast-iron pressure tanks into which the finished

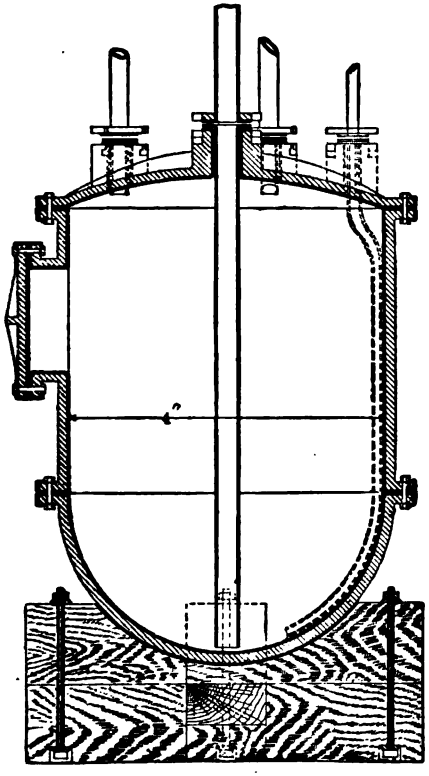


FIG. 3 SECTION ON LINE A B

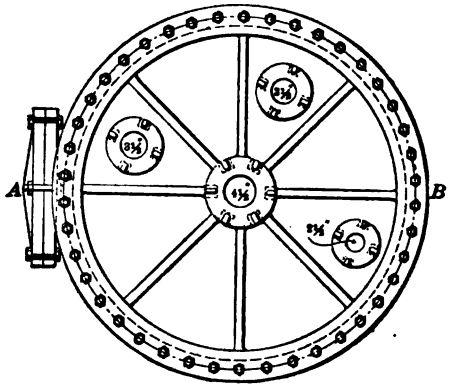


FIG. 2 PLAN SHOWING SIZE OF OPENINGS

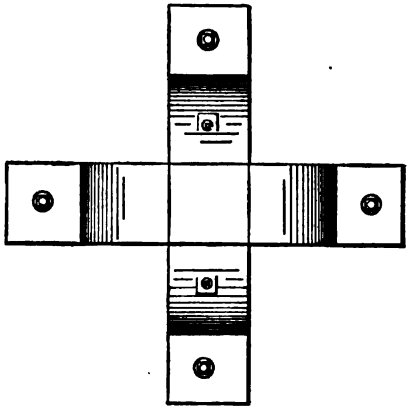


FIG. 4 PLAN OF SUPPORTING FRAME

FIGS. 2, 3 AND 4.—CAST IRON PRESSURE TANK.

charge is drawn. On account of the residues the pressure tanks are in an upright position and are constructed as follows: The body consists of two cylindrical sections 4 ft. long and 4 ft. 6 in. in diameter, the bottom being of a spherical section of 2 ft. 3 in. radius and the top rounding upward to a height of 6 in. above the rim. The sections are tightly flanged, with a rubber gasket between. Four pipe connections are made through the top, the discharge pipe entering through the center passes nearly to the bottom and the filling pipe, air inlet and air outlet pipes are conveniently arranged around it. By proper connection with the filling pipe and by the use of valves, one pressure tank is made

to serve four stir tanks. The upper cylindrical section is provided with a manhole, and the tanks are lined first with lead and then with wood to protect the lead from wear by abrasion. The air pressure required is from 40 to 50 lb. Fig. 2 shows a top view, and Fig. 3 a vertical cross section of an upright pressure tank, while Fig. 4 illustrates the supporting frame. This tank is somewhat smaller than those used at Argentine, and has one cylindrical section instead of two. The general arrangement, however, is the same. The air inlet extends downward along the side, ending near the discharge pipe, in order to keep the residues near the outlet in a loose condition and prevent the pipes from clogging. For this reason it is advisable to have a small stream of air enter during filling. The residues are rather heavy and pack tightly around the discharge pipe in quite a thick layer, which, on applying the pressure, would be forced in this compact condition into the discharge pipe and the pipe leading to the filter press, causing them to become clogged.

The pulp is forced by the pressure tank into a large filter press of which there are five in use. The press is 25 ft. long over all and has hard wood frames and plates 4 ft. square. The clarified solution flows from the press to a lead-lined tank from which it is elevated to the purifying towers by means of a pressure tank, the hard-lead pumps formerly used for handling copper solution having proved failures. The apparatus in which the refining of the solution is done has been simplified and its cost of construction greatly reduced. The lead and iron framework of the towers has been replaced with California redwood which makes an excellent material to resist the action of hot cupric sulphate solution. The new towers, 9 ft. in diameter at the bottom, are constructed of staves 16 ft. long and 4 in. thick, which are well hooped with round iron; the bottom and top are flat. The towers are firmly fastened to a strong wooden trestle, which in turn is anchored to a concrete foundation. This construction is called for to guard against the oscillating movement of the tanks from the action of the contained solution, which is set in violent motion by the ascending air. Inside the tower, about 19 in. above the bottom, the 4-in. lead air pipe enters and is connected with a perforated 6-in. lead pipe which extends diametrically to the opposite side and is closed at the farther end. Outside of the tower the air pipe extends upward to above the top of the tower, and thence downward to the discharge pipe of an air compressor. This arrangement is necessary in order to prevent the solution from flowing to the air pump. At the same level with the air inlet, the 4-in. discharge pipe enters, which is provided with a hard-lead valve placed close to the outside of the tower. At about the same level a 1-in. steam pipe enters for heating the charge. The lead steam coil formerly used has been discarded and the heating is now accomplished by direct steam. This change was necessary as the lead coil required frequent repairs, and, moreover, the heating effect of direct steam is much greater than that of a steam-heated coil. The solution does not lose in strength through the condensation of the steam, the evaporation which is favored by the ascending air fully equalizing the dilution. The top of the tower is provided with an 8-in. pipe for the escape of the vapor and air, and with a 4-in. pipe for charging the crude solution. An opening in the center supports a small hopper which is filled with roasted matte, and by

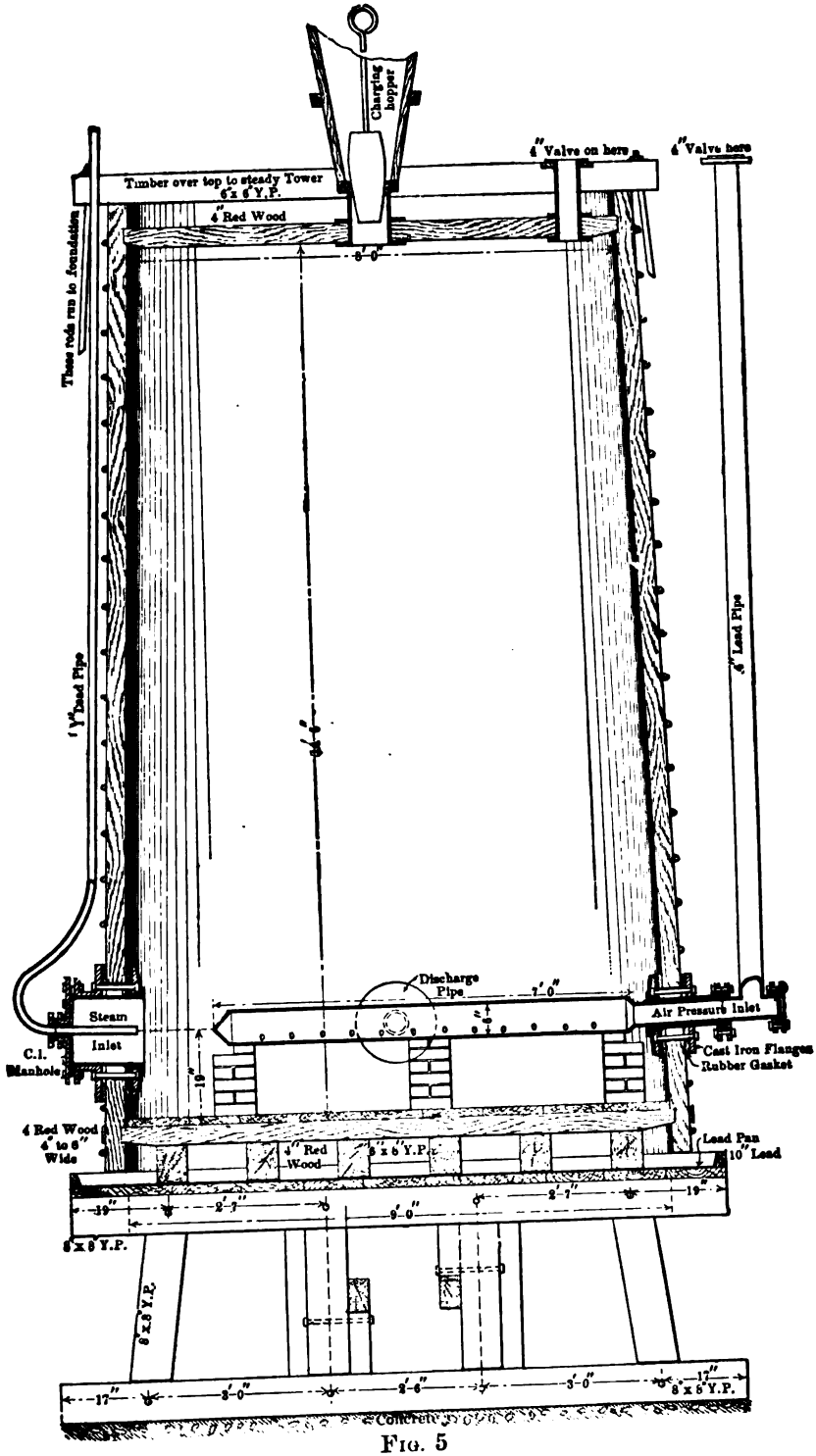


FIG. 5

HOFMANN'S TOWER FOR REFINING CUPRIC SULPHATE SOLUTIONS.

lifting a cone valve the charging is kept under good control. By the action of the air and the cupric oxide of the roasted copper matte in the neutral solution, the impurities are oxidized and precipitated. The perforated cones, of which there were three in each tower for the distribution of the compressed air throughout the solution, have been replaced by a sufficiently large perforated pipe. This change simplifies the construction without impairing the efficiency of the tower. In charging the towers, room must be left for the increase in volume of the solution which occurs as soon as the air is supplied. A tower of the new type can be charged with about 5,000 gal. of solution, and as three such charges can be refined in 24 hours the working capacity of one tower is 15,000 gal. per day. Eight of these towers are in use at the Argentine plant. Fig. 5 shows a vertical section of a tower of the latest construction. The air inlet pipe, which is horizontal within the tank, has only its lower half perforated to prevent the inflow of matte and precipitate. The steam pipe was formerly inserted direct through the wood, but as the latter became affected by the heat, it now enters through the manhole cover. A similar effect was noticed with the bolts which passed through the wood to hold the flanges of the manhole, air inlet and discharge pipe. In the new construction these holes in the staves are cut much larger, and neither the frame nor the bolts are in contact with the wood. This is shown in the illustration. The two pipes are arranged in a similar manner. All iron parts on the inside of the tower are covered with heavy sheet lead.

When the reaction is completed and the solution freed from impurities, the charge is drawn off and forced through a filter press. The tower residues, consisting mainly of precipitated iron, arsenic, antimony and some undecomposed matte, contain also some basic copper sulphate. To remove the last named substance the residues are treated in a stir tank with a 2·5 to 3% cold acid solution, which dissolves the basic copper salt leaving the impurities unaffected with the exception of iron, which is acted on very slightly. The refined solution is conveyed to settling tanks from which the evaporating tanks are supplied.

The evaporating department furnishes the crystallizing department with about 90,000 gal. of concentrated solution daily. To supply this amount an improvement over the old pan evaporators with under-fire or steam coils was requisite, and as vacuum evaporators could not be adopted, I have introduced an economical and effective evaporator, which is illustrated in Figs. 6 and 7. The principles observed in the construction of this evaporator are the application of the hot furnace gases direct to the heating of the solution, and the almost complete utilization of the heat contained in them. The apparatus consists of a flat wooden tank with the exception of a 2-ft. space at the front end, which is made of steel, so that the wood will not be in too close proximity to the furnace. The tank is 65 ft. long, 12 ft. wide and 2 ft. deep, and is lead-lined, the two ends having much heavier lead lining than the sides and bottom. It is traversed longitudinally by 13 six-inch lead pipes, and rests on a wooden trestle-work of a proper height to correspond with the height of the furnace. At the furnace end in each lead pipe is inserted a 5-in. iron pipe 4 ft. long provided at the outer end with a flange. The iron pipes serve to protect the lead pipes from immediate direct con-

tact with the red hot gases from the furnace, they also make the connections between the lead pipes of the tank and the iron pipes of the furnace.

The furnace is comprised of the fire-place *C*, the dust chamber *D* and the heat distributing chamber *D* . At a proper height in the wall of the distributing chamber nearest the tank are 13 openings, in each of which is inserted a short cast-iron pipe, 5 in. in diameter with a flange at the outer end. Each pipe is connected with its corresponding lead pipe in the tank by a cast-iron S-shaped elbow *Y*, which allows the introduction of the compressed-air pipe *E* for removing any accumulation of ashes in the lead pipes of the tank.

An American underfed stoker is used for the slack coal fuel, and affords practically perfect combustion which is of great importance, as otherwise the lead pipes would soon become coated with soot and lose much of their efficiency to transmit the heat to the solution.

The opposite end of the lead pipes in the tank are connected with the brick suction chamber *O*, which in turn is connected by a galvanized iron pipe *R* with a suction fan *P*, the gases being discharged into the underground flue *S*. This flue serves in common to collect the waste gases from 11 evaporators, and terminates outside the building into a brick chimney 40 ft. in height.

The top of the pan is closed with a wooden cover and joists *G* are placed across the pan about 5 ft. apart, having cleats fastened to the lower side, as shown in Fig. 6. The spaces between the joists are covered with boards resting on the cleats and pushed close together, but not nailed, so that the whole or part of the cover can be easily removed. About 14 ft. from the front end of the tank is a 14-in. suction pipe *L*, connected with the main suction pipe *M*, which crosses all of the evaporators to remove the water vapors. This main suction pipe is constructed of wooden staves kept tight by hoops. The suction pipe *L* was first made of lead, but by some unexplained chemical reaction, it was destroyed after a few months of operation. Later a wooden tube was substituted, which was made in the same manner as the main tube. The latter is in connection with a large fan having the housing and wings of sheet copper and the shaft and arms of brass. This fan rapidly removes the vapor from each evaporating tank and by its use the building, even in cold winter weather, is entirely free from steam. A wooden stack serves for the discharge of the fan, and the strength of the exhaust is regulated by a wooden slide *N* inserted below the suction pipe *L*.

Close to the end of the evaporating tank, and resting on the cover is the lead-lined feed box *V*, from the bottom of which is a short pipe or nipple leading into the tank. The solution supply-pipe *T*, which crosses all the evaporators, is connected with the large supply tanks and serves to convey the solution to each evaporator by downtakes *U*. The outlet of the evaporating tank is in the side near the furnace end about 4 in. above the hot-air pipe *B* (Fig. 6).

The operation is conducted in the following manner: the pan is first filled to the level of the outlet with the copper sulphate solution to be concentrated, the fire is then started and the suction and stoker fans set in motion. The big copper fan is not started until the solution becomes hot enough to generate steam. During the operation the level of the solution is kept at the same height by the occa-

[1] United States Patent No. 683,281, Sept. 24, 1901.

to avoid cooling, which would cause crystals to form in them. In construction the troughs are of California red-wood, 10×11 in., in sections of 16 ft. The ends of the sections butt together and have an intervening rubber gasket. The sections are drawn together by iron flanges fastened to the sides of the trough a few inches from the end, iron bolts passing through both flanges. Brass screws are used in making the troughs, as iron nails or screws would not last. The joints between the bottom and the sides are coated with a fairly thick cement, which is made by boiling together waste rubber, resin, linseed oil, and ferric oxide. The cement when properly made should be quite liquid when very hot and stiff when cold, but never brittle or so hard that it cannot be kneaded between the fingers; nor should a piece of the stiff cement become liquid in water at a temperature of 80 to 90°C. The cement is elastic, and, as it never hardens, it keeps the joints well filled and overcomes the difficulty which arises from the shrinkage of one board from another. It has given very satisfactory results in the Argentine plant and there has been absolutely no leakage in the troughs, which in aggregate length amount to nearly half a mile.

The crystallizing department has 112 tanks, each of 720 cu. ft. capacity arranged in long rows intersected by several cross passages. Between each two rows is a track for transporting the blue vitriol crystals, on either side of which is a cement channel to receive and convey the mother liquor. The lead-lined wooden crystallizing tanks did not prove satisfactory, as the change in temperature caused by each filling with hot concentrated solution expanded the lead which did not subsequently contract in cooling; as a result in course of time the tank lining became wrinkled and broken, and caused leakage and expensive repairs. The entire floor of the blue vitriol plant is made of cement in order to collect any leakage that may take place. At present the tanks are made of concrete, and, though far superior to the original lead-lined wooden tanks, they do not come up to expectation because they also are affected by the sudden change in temperature when filled with the large bulk of hot concentrated solution. Although constructed with walls 20 in. thick, small cracks result, but leakage can be prevented by plastering a little cement on the outside of the tank. An experimental tank which has now been in use for several months seems to answer all requirements. It is built of bricks, having in the center of the walls a 2-in. space filled with a mixture of asphaltum and sand, which extends also from the sides under the bottom of the tank thus practically forming a tank by itself imbedded in the brickwork. When heated by the sudden filling of the tank with hot solution, the asphaltum softens, and when gradually cooled it contracts without cracking.

On the top of each tank are movable wooden frames supporting numerous strips of lead, on which the crystals form as well as on the sides and on the bottom of the tank. The solution remains seven days in the tank. At the expiration of this time the mother liquor is drawn off and the crystals removed. Ordinarily 16 tanks are discharged daily, but during the hot summer months more time has to be given for the crystallization, and fewer tanks are discharged and refilled daily.

The mother liquor is drawn off through a brass tube close to the bottom of the tank and flows in the above-mentioned cement channels in front of each row

of tanks direct to the three pressure tanks placed in a pit. These tanks elevate the mother liquor to large storage tanks, where it is mixed with fresh copper sulphate solution from the dissolving and refining departments, and is ready to supply the evaporators. When the crystallizing tank is empty, the movable frames with the lead strips and adhering crystals are lifted by a block and chain and the crystals knocked off with a wooden paddle. The crust of crystals from the sides is broken down. Rails are laid in recesses near the rim of the tanks so that the rails of the two opposite rows of tanks form a track for a hopper mounted on wheels. The crystals are shoveled with copper shovels into this hopper, which fills the push car underneath through a spout with slide in the center. As the tanks are 6 ft. deep, the crystals have to be thrown at least 7 ft. high, and in doing this work some of the crystals unavoidably fall back into the tank, fre-

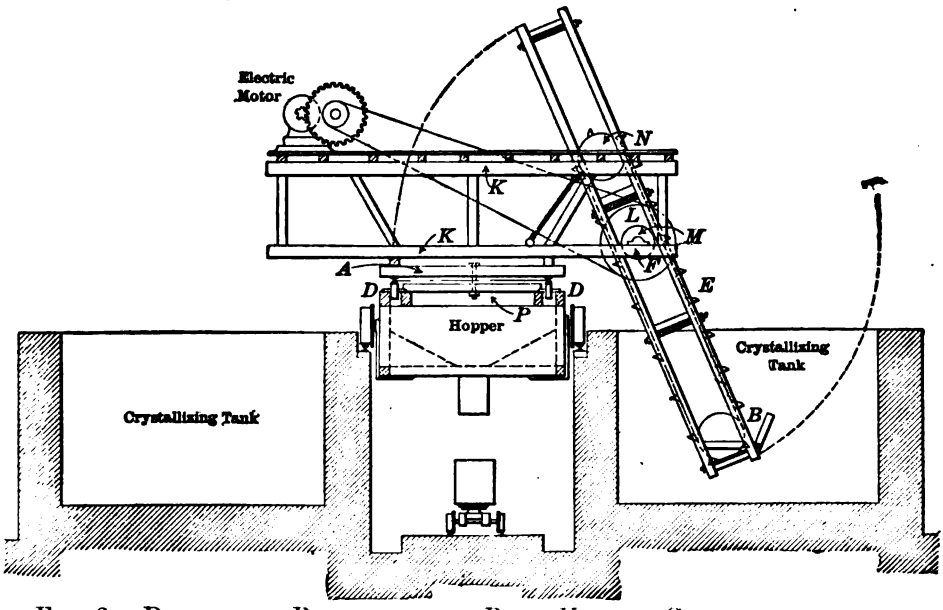


FIG. 8.—DEVICE FOR REMOVING THE BLUE VITRIOL CRYSTALS FROM THE CRYSTALLIZING TANKS.

quently striking the shoveler. It was found that this was very injurious to the men, especially in summer, when they are dressed scantily and perspire freely. Their bodies became covered with deep sores, obliging them to be replaced by new hands. These sores were not dangerous, but were very painful, and the men naturally shunned the work. Finally this branch of the plant was closed during the months of July and August.

To overcome this very disturbing feature, I have constructed and set in successful operation the device illustrated in Fig. 8. On top of the hopper is mounted the frame *KK* with a turntable and circular track underneath which rests on a number of stationary wheels and is kept in place by the pin *P*. The object of this turntable is to make the apparatus available for opposite rows of tanks by rotation through 180°. The frame *K* is provided with a belt elevator *E* with

copper cups, which can be brought into a horizontal position by means of the shaft *F*. On the same shaft are the pullies *L* and *M* which drive the elevator pulley *N*. The lower end of the elevator is provided with the boot *B*, which can be brought down to within a short distance from the bottom of the tank and into which the crystals are shoveled. The power is imparted by an electric motor on the platform of the frame, which receives the electric current by an overhead wire with trolley extending along the rows of tanks. From the time this device was introduced the men were protected from the injurious effect of the blue vitriol crystals even during the hot summer months, as they had to shovel them only a short distance above the floor.

The push cars containing the crystals are wheeled to the sizing and drying department and lifted by a platform elevator to the rim of a bin, into which the crystals are dumped. From this bin the crystals are fed between a fast-revolving roll and a plate provided with teeth, which breaks the crusts of crystals without injuring the individual crystals. After passing the rolls the crystals drop into a small hopper having a short worm conveyor of copper at the bottom, which feeds a belt-elevator provided with copper cups. The elevated crystals drop into an inclined trough and are washed by a stream of mother liquor. They then drop into a hexagonal revolving screen having the shaft and arms of brass. The screen itself is of maple wood perforated with holes 0·375 in. in diameter. All crystals smaller than 0·375 in., together with the mother liquor, pass through a second inclined trough to another revolving screen, which is of sheet copper having 0·125-in. perforations. The mother liquor, with the very fine crystals, dirt, and sediment, after leaving the second screen is conveyed to an agitating tank and heated by a steam jet to dissolve the very fine crystals. The resultant solution is finally sent through a filter press, the clear liquor flowing to the storage tanks.

By using mother liquor to wash and screen the crystals, the fine crystals are as clean and pure as those of larger size. At the present time the blue vitriol crystals are dried in 10 brass centrifugal machines and conveyed to the storage bins.

The crystals, having been obtained from a neutral solution, are of a very deep blue permanent color which is not affected by light except in the direct rays of the sun. They do not change into a bluish white powder, which is the case with crystals made from an acid solution.

COPPERAS.

THE production of copperas in the United States during 1901 was 23,586 short tons, valued at works at $112,366 against 12,374 short tons valued at $96,517 in the previous year. These figures do not include the quantity calcined for the manufacture of pigments, which is reported under production of "Iron Oxides."

Ferrous sulphate ($FeSO_4,7H_2O$) or as it is technically called "copperas," is produced in the United States principally as a by-product of the wire and sheet steel industries of the country. The wire, rods and sheets are subject to a bath of dilute sulphuric acid for the purpose of cleaning and brightening the metal. This bath is used until it accumulates a large quantity of loose particles of metal, etc., when it is replaced by a new mixture. The waste pickling liquor is allowed to flow away as much as possible, but in thickly settled communities this is opposed on the ground of injury to sewage pipes, contamination of water supply, etc. In some places this waste acid is not allowed to enter any waterway, although some authorities claim that it is beneficial to a stagnant flow. In localities where this waste acid is not allowed to flow away, iron and steel manufacturers utilize it for making copperas. The usual method followed is to collect the waste acid from the different pickling rooms into convenient tanks or reservoirs, later removing it in lead-lined tank cars or by gravitation through pipe lines to the works (for treatment) which must be located outside the busy portion of the community on account of the acid fumes produced. When received at the copperas works, the liquor is tested to ascertain its percentage of iron, acid, etc., and suitable additions are made in order to form a liquor of proper composition and strength. It is then run to large boiling tanks for the purpose of evaporating the excess of water which requires from three to four days to bring it to the proper strength for crystallization. The hot liquor is then drawn off into large vats or crystallizers and allowed to cool. The crystals form on the sides of the vats or on iron rods suspended therein and requires from three to ten days, according to the temperature. The crystals are then detached and submitted to an additional drying process in order to eliminate any surplus moisture, and when this is done they are ready to be packed in barrels and marketed.

Copperas crystals are used in the manufacture of inks and blues, for polishing plate glass, for dyeing cottons and woolens, and in different branches of the chemical trade.

The bottom settlings of the tanks are taken by some of the manufacturers and calcined in furnaces with the aid of lime or similar material to make Venetian reds, Indian reds and iron oxides. The bottom salts are also used to some extent as a fertilizer and disinfectant, as a precipitant in some forms of chemical treatment of sewage and in gas works for purifying purposes.

The largest producer of copperas is the American Steel & Wire Co., whose plants are operated in connection with the manufacture of wire at Worcester, Mass., Cleveland, O., De Kalb and Waukegan, Ill. Among the other producers are the Pennsylvania Salt Mfg. Co., Natrona, Pa., C. K. Williams & Co., Allentown, Pa., S. P. Wetherill & Co., Newcastle, Pa., The Atlantic Dynamite Co., Dover, N. J., Joseph Wharton, Camden, N. J., Charles Lennig & Co., Philadelphia, Pa., the Forest City Manufacturing Co., Ellwood, Ind., and the Stauffer Chemical Co., of San Francisco, Cal. Small shipments of copperas are also made from time to time from Steubenville, O., where it is formed naturally by the oxidation of pyrite.

The price of copperas at New York at the commencement of 1901 was about $10 per ton against an average of $14 per ton for the previous year. On account of the advent of new manufacturers in the field during the latter part of 1900, and the consequent increased production in excess of the normal demand, prices declined to $7 per ton, a figure which ruled the greater part of the year. These quotations are for carload lots, an additional $1 per ton being asked for lots of smaller size. At $7 per ton, which includes cooperage and transportation, there is a loss to the manufacturer, and for this reason two or three plants have discontinued operations during the year. The present capacity of the various plants now engaged in the industry is much in excess of the demand and unless some new outlet for the product should be found it will be a problem to dispose of the waste liquors in this form. There is no opportunity for export of copperas for the reason that England, France and Germany also produce it as a by-product in larger quantities and at a lower cost than the United States.

PROGRESS IN ELECTRO-CHEMISTRY AND ELECTRO-METALLURGY IN 1901.

By John B. C. Kershaw.

The electro-chemical and electro-metallurgical industries have not made such striking progress in the year 1901 as in the two previous years—1899 and 1900; and in some branches the results of overcapitalization and overproduction in the earlier years, have produced the customary evils, and have led to the closing down of plants and compulsory liquidation of the companies that owned them. These evils have been especially manifest in the calcium carbide industry, and the number of factories manufacturing this product at the end of 1901, is probably less than one-third of the number in operation two years ago. New developments, however, are always liable to be unwisely boomed, and it must not be imagined that because the carbide industry has suffered considerably from speculative finance, that the electro-chemical and electro-metallurgical industries generally are in a bad way and liable to gradual extinction.

The details given in the following pages show that 41 distinct products are now manufactured by aid of the electric current, that in the majority of cases the output of these products is increasing, and that a large number of the companies operating these new processes, can show highly satisfactory financial results.

No very noteworthy new processes relating to electro-chemistry or electro-metallurgy have been widely developed in 1901. A new method of preparing bauxite for use in the electrolytic baths for aluminum manufacture, may however cheapen the production of the light metal, and several patents have been granted for electro-metallurgical treatment of zinc ores which may possibly have an important future. Details of a remarkably simple process and apparatus for production of alkalies and chlorine (the "bell" process), have also recently been made public, although this process has been in operation several years in Austria. Full particulars of these patents and processes will be found under their respective headings.

Alkalies and Bleach.—No striking progress has occurred in the electrolytic alkali and bleach industry during 1901. The number of works remains stationary at 31, and the power available in these is about 46,000 H.P. The most successful

works appear to be those using the Castner and the Elektron Companies' processes, but even these have ceased for the moment to show any further expansion. It is not yet possible to present any very reliable figures for the total output of the electrolytic alkali works in Europe and America; since in numerous cases the power development is in excess of that utilized for the electrolytic decomposition of salt. Figures for individual works can, however, be given. At the new Middlewich works of the Electrolytic Alkali Co., a 400-H.P. unit of plant was started in April, 1901, and a current of 4,000 amperes and 50 volts was used to work 22 cells of the Hargreaves-Bird type. The plant has since been doubled and in October it was reported that 50 cells were yielding 13 tons of soda crystals and 9 tons of bleaching powder per day. This company, and the Castner-Kellner Co., at Weston Point, use multiple-effect vacuum evaporating pans for concentrating their alkali liquors.

At Bitterfeld, Griesheim, and Rheinfelden, four electrolytic alkali works are operating, and from an official communication, the combined output of these works now equals 25,000 tons caustic potash and 40,000 tons bleach per annum. With these figures before one, it is interesting to note that in 1900, Germany imported 398 tons bleach and exported 25,953 tons of the same commodity. The demand in Germany for bleaching powder is therefore now well covered by the domestic production.

In this connection the following figures showing the proposed changes in the German import tariff for caustic alkali and bleach are of importance:—

Caustic Alkali.—Old tariff, 50c. per cwt. New tariff, 42·5c. per cwt.

Bleaching Powder.—Old tariff, 36·5c. per cwt. New tariff, 24·5c. per cwt. Though reduced, the duties may still be regarded as prohibitive.

In France the position is somewhat similar, for the domestic production is estimated to amount to 30,000 tons, while the exports in 1900 amounted to 11,300 tons. In both France and Germany therefore, the market for bleaching powder is suffering from overproduction, which retards the development of the electrolytic alkali industry in the two countries. The greater portion of the bleach output in France, is still supplied by the older Le Blanc process, and according to a reliable authority only 5,000 of the 30,000 tons made in 1900, was produced by the electrolytic decomposition of salt.[1] This is particularly noteworthy, for of the five electrolytic alkali works in France, only one, that at Lamotte, appears to be working satisfactorily.

With regard to the profits made by the companies working the various electrolytic processes, the English Castner-Kellner Alkali Co., shows a gross profit of $314,760 and a net profit of $216,048 for the year ending March 31, 1901. A dividend of 5% was paid as compared with 8% in1900, and $48,000 carried to the reserve. The fall in profits and dividend was attributed to the loss of the South African market for cyanides, and to the high price of fuel and raw materials. The Electrolytic Alkali Co., operating the Hargreaves-Bird process at Middlewich, England, reports a net profit of $5,956 for four and a half months' work of 36 cells, and considers this a satisfactory result for the start of a new plant. The

[1] *Chemiker Zeitung*, 1901, p. 129.

Chemische Fabrik Griesheim Elektron paid 5% for the year ending December 31, 1900, as compared with 16% for 1899. This firm controls several subsidiary companies and works engaged in the electrolytic alkali industry, and owns an aniline color and picric acid works at Griesheim near Frankfort. A disastrous explosion and fire occurred in the picric acid department on April 25, 1901, and the reduced dividend for 1900 is probably a result of the losses incurred in that disaster, by which 14 men were killed and 100 injured, in addition to enormous destruction of plant and property.

The Electro-Chemical Co., which operated the Richardson and Holland gravity process at St. Helens, England, since 1895, went into liquidation during 1901.

The profits to be obtained in the electrolytic alkali industry depend largely upon the working costs of the process used, and where diaphragms and mercury are dispensed with, these may be reduced to a minimum. The following cost-estimate by Seibert has been published during 1901, and is of interest since it appears to be based on practical knowledge of one of the German secret processes.[2]

ESTIMATE OF COST OF 10,000 KG. 91% CAUSTIC POTASH AND 15,550 KG. 35% BLEACHING POWDER.

Capital outlay upon plant, 700,000 marks.

	Marks.		Marks.
Electrical power, 1,050 H.P. gross	400	Wages and repairs	570
Potassium chloride	1,922	Depreciation	140
Carbon anodes	137	Management	100
Lime	140	Interest on capital	160
Packages	374		
		Total	3,943

Taking current prices for caustic potash and bleaching powder, this estimate shows the handsome profit of 5,227 marks, or 37% on the capital. The market for caustic potash is, however, a restricted one, though it is well known that the manufacture is a profitable one.

Details of two processes of interest, have been published during the past year—namely, of the Acker "Fusion" process, and of the Aussig "bell" process. Both of these are working upon an industrial scale—the former at Niagara Falls, N. Y., and the latter at Aussig in Austria, and at Bitterfeld and two other places in Germany. The Acker process depends upon the use of molten salt as electrolyte, with a cathode of fused lead. The first patent granted for this use of molten lead was No. 13,568 of 1893, to Vautin, a British inventor. A steam injector is used in the Acker cell to cause circulation of the molten lead cathode, and the decomposition of the alloy of lead and sodium is effected by this steam in a separate vessel. Fig. 1 is a diagrammatic section of the Acker cell. The chief advantages claimed for the process, are high output per unit of plant and reduced charges for fuel, since 98% caustic soda can be obtained in the decomposing vessel. No efficiency figures for this cell have yet been published. The mechanical difficulties that have to be overcome in carrying out this process on a large scale are great and it is yet doubtful whether all of these have been surmounted. In July,

[2] *Elektrochemische Zeitschrift*, November, 1901.

1901, however, Mr. C. E. Acker stated that the process was in successful operation and that solid caustic soda was being produced without any evaporation. The works at Niagara Falls are planned to utilize 2,400 K.W. electrical energy.

The "bell" process is an old one, and has been experimented with at Aussig since early in the nineties. Details of the cell construction are still kept secret, but the broad features of the method are described in English Patent No. 16,129 of 1898. Fig. 2 shows a diagrammatic section of the cell. In this diagram *a* represents the anode, *d* the bell, and *c* the cathodes; while fresh brine is fed into the anode chamber by the pipe *e*, and the chlorine gas escapes by the pipe *g*. The caustic alkali solution leaves the cell by the overflow pipe *f*. The process is a gravity process, no diaphragm being used, and by careful regulation of the respective positions of the anode and cathode and of the flow of brine to the anode compartment in the interior of the bell, it is said to be possible to keep distinct the three layers of electrolyte present in the cell. Owing to the absence of oxygen

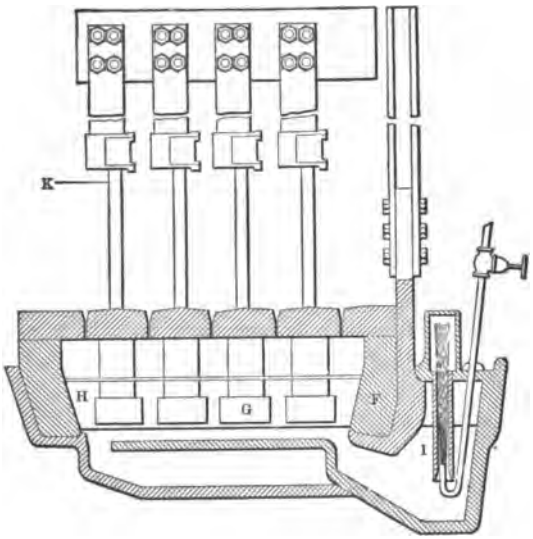


FIG. 1.—CROSS SECTION OF THE ACKER ELECTROLYTIC FURNACE FOR ALKALI.

compounds in the anode compartment of the cell, the life of the carbon anodes is enormously increased and ordinary thick lamp carbons are said to last 21 months. The current efficiency is reported to lie between 85 and 90%, and the strength of alkali solution obtained varies between 100 and 150 g. NaOH or KOH per liter. The "bell" process is therefore one of the simplest of the electrolytic alkali processes now in use and the running costs would appear to have been reduced to a minimum. It is noteworthy that careful attention to details of construction and working has turned a process which failed at St. Helens into a success. The process has passed beyond its experimental stage and 24,000 "bells" are now used in the four works named above, a number which will be increased early in 1902. It is believed that the Bitterfeld and Griesheim works are employing this process although official confirmation cannot be obtained. A new patent has just been

granted relating to the treatment of the mixed potassium hydrate and chloride liquors obtained by the "bell" process. The liquors are boiled down to the point when KOH commences to crystallize out. Cooled to a temperature lying between 35° and 60°C., this concentrated solution yields crystals of caustic potash containing 70% KOH, 29·5% H_2O, and only 0·073% KCl. The latter salt only commences to crystallize out in quantity when the temperature of the mother liquor has sunk below 35°C.

The Oesterreichische Verein fuer Chemische Production, which owns the "bell" patents, and the Salzbergwerk Neu Stassfurt, another Austrian company, have now combined to work these two patents in Austria, and a considerable increase in the Austrian production of electrolytic alkali and bleach may be expected in the near future.

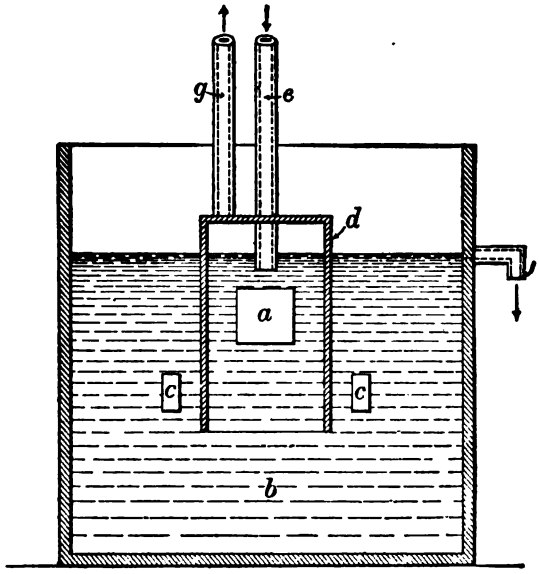


FIG. 2.—DIAGRAMMATIC SKETCH OF THE "BELL" TYPE OF GRAVITY CELL.

From a recent communication with the Austrian company controlling the "bell" patents, an estimate of costs has been taken which, owing to the importance of the process, is here reprinted in full. For the sake of comparison with Seibert's estimate given above, all weights and values are expressed in kilograms and marks.

Daily costs of a plant consisting of four 600-H.P. generating units, producing 14,000 kg. 90% caustic potash and 21,600 kg. bleaching powder per day. Outlay on plant, 3,000,000 marks. Working capital, 200,000 marks.

	Marks.		Marks.
Electrical energy (1,400 K.W. for 23 hr. per day)	507·50	Packages	350·00
Steam for concentrating caustic liquors	136·50	General expenses (20%)	1,038·45
Potassium chloride	8,332·00	Depreciation (7% on 3,000,000 marks)	573·65
Caustic lime (13,400 kg. @ 15·8 M. per 1,000 kg.)	211·75	Interest (5% on 3,200,000 marks)	436·90
Wages	472·50		
Repairs	367·50	Total	7,426.75

Taking the prices for caustic potash and bleaching powder previously given in the table referred to earlier in this paper, the value of 14,000 kg. 90% alkali and 21,600 kg. 35% bleaching powder works out to 12,740 marks. This leaves a margin between the actual cost and sales value of the products sufficiently wide to cover all manufacturing contingencies and to leave a satisfactory surplus.

Details of an interesting laboratory investigation by Adolph, using the "bell" type of cell have been published during 1901.[3] The best results were obtained with platinum anodes, the current efficiency under favorable conditions as regards temperature and concentration, rising to 97·68%. With carbon anodes the results though lower were still eminently satisfactory, efficiencies of 92·97 and 92·68% being recorded in two separate experiments. The possibility of working continuously with this form of cell was proved by an experiment lasting seven days, during the last five of which, fresh salt solution was fed continuously into the anode compartment of the cell. The current efficiency obtained during this trial was 82·1%. Adolph closes his paper by urging the technical importance of these results, and he will no doubt be gratified to learn that the "bell" process is already an industrial success and is rapidly extending.

Franke has described during the past year laboratory investigations with a new form of mercury cell in which a falling stream of mercury is used as cathode between carbon and platinum anodes of large superficial area.[4] The advantages claimed for this type of cell compared with the other forms of mercury cell are higher electrical current efficiency and a reduced weight of mercury. In a large scale experiment, a flow of 500 g. of mercury per second sufficed to carry a current of 160 amperes at 4 volts pressure, with carbon anodes, and when platinum was substituted for carbon, a flow of from 100 to 150 g. mercury sufficed to carry the same current. Cells of glazed stoneware only 31·5 in. square, provided with alternative anodes and cathodes, can be utilized to pass currents of 3,000 amperes and 4 volts, so this form of cell certainly economizes space. Owing to the rapid flow of mercury through the cell, the amalgam obtained is not rich in sodium and this, though an advantage from the current efficiency point of view, is a disadvantage when the decomposition of the amalgam has to be considered.

Coehn and Geisenberger have also patented a novel procedure for overcoming some of the difficulties met with in the electrolysis of brine on a commercial scale.[5] The principle of their method is the separation of the alkali hydrate in a solid form at the moment of its formation at the cathode—a result they achieve by working the electrolyzer at a temperature lying between —30° and —38°C. The form of apparatus required for attaining this low temperature is complicated, and as the expenditure involved would be excessive, in addition to loss of energy efficiency, the method though ingenious can hardly be considered of practical value.

The question of anode material still remains an important one for the electrolytic decomposition of sodium or potassium chloride. The statement of the Aussig Co. that with its "bell" process, when properly worked, ordinary thick

[3] *Zeitschrift fuer Elektrochemie*, May 2, 1901.
[4] *American Electrician*, March, 1901.
[5] *Elektrochemische Zeitschrift*, Sept. 1, 1901; German Patent No. 121,982, of 1900.

lamp carbon will last nearly two years, is most remarkable, and shows that the companies using this process must have a great economic advantage over those employing processes that involve frequent renewals of the carbon anodes. The Castner-Kellner Alkali Co. is reported to be using the Acheson graphitized carbons, which are no doubt one of the best forms of artificial carbon for anodes now on the market. Formerly this company prepared carbon for its own use. But even graphitized carbons slowly disintegrate in most forms of electrolytic alkali cell and this consumption and waste of carbon has a further disadvantage besides that of cost. The carbon oxidized at the anode, escapes from the cell as carbon dioxide with the chlorine gas, and its presence leads to difficulties in the production of high strength bleach. To such an extent is this difficulty experienced in some works, that special means have had to be taken in order to free the chlorine gas from carbon dioxide before admitting it to the bleaching powder chambers. Experimental researches carried out by Sproesser with anode carbons in alkali chloride cells during 1901, prove that its waste and disintegration is caused by the presence of oxygen compounds in the electrolyte at or near the surface of the anode, and the life of the carbon anode increases as the formation of these compounds is hindered or suppressed.[6] This result appears to have been satisfactorily achieved only by the Aussig bell cell, which is therefore the most economical as regards cost of anodes in actual use.

Nothing very new has been published on the subject of diaphragms during 1901. Seibert in the article already referred to, states that in the German works using a diaphragm process, it is customary to form diaphragms *in situ* in the cells by the use of a mixture of salt and cement. When this has hardened, the salt is dissolved out and a porous cement diaphragm remains ready for use. Such diaphragms are said to last six months and to possess a longer life than asbestos diaphragms. In this connection it is stated that a curious sickness broke out during 1901 among the men who remove the diaphragms from the cells at the electrolytic alkali works at Lamotte, France. The "Elektron" process is used at this works, and the disengagement and breathing of Cl_2O compounds is believed to be the cause of the trouble. In this respect the "bell" and mercury processes have a common advantage, for neither requires diaphragms in the cell.

As regards the electrical efficiency of the various processes, only few figures have been published during the past year. From authoritative sources it is stated that at the Middlewich works of the Electrolytic Alkali Co., 1,000 watt-hours decompose 1 lb. sodium chloride. The theoretical figure is 2·08 lb. and the energy efficiency of the process therefore works out to 48%, as compared with 54% in the trial runs at Farnworth.[7] The current efficiency with the Aussig bell process is stated to lie between 85 and 90%. As no diaphragm is used, the E.M.F. required by this process must be low and the energy efficiency will therefore work out over 50%. It would be interesting to compare with these figures those obtained by the Acker fusion process at Niagara Falls, but up to the present, no efficiency figures for this process have been published. Efficiency figures for the very similar Hulin fusion process, are given in the article just referred to.

[6] *Zeitschrift fuer Elektrochemie*, November and December, 1901. [7] *Electrician* (London), March 4, 1898.

Patent litigation in the electrolytic alkali industry during 1901 has been restricted to preliminary legal skirmishes in the British courts relating to the new case, the Commercial Development Corporation vs. the Castner-Kellner Alkali Co. The decision in favor of the former company in the appeal case carried to the House of Lords in 1900,[8] did not exhaust the possibilities of the situation, and the Commercial Development Corporation is now taking action against the rival company on the basis of English patents granted to Atkins and Applegarth in the years 1882, 1886, 1888 and 1890. These patents have passed into the possession of the plaintiff company, but the situation has been complicated by a clause in the purchase agreement under which Atkins and Applegarth (the vendors) were to proceed against the Castner-Kellner Co., for infringement. Atkins and Applegarth have not carried out this action, however, and the legal procedure in this new infringement case has consequently got itself into one of those tangles much beloved by the legal profession—on account of the opportunities they afford for a display of legal acumen and for the piling up of handsome fees. The Commercial Development Corporation has at last received permission to proceed in its own name with the action entered for trial in the names of Atkins and Applegarth, and possibly by the end of the year 1902, this case may have progressed through the first stage and be awaiting the inevitable appeal proceedings.

ALUMINUM.—(See the special article on this subject elsewhere in this volume.)

BULLION REFINING.—The electrolytic methods of refining gold and silver are slowly making headway in Europe and America, and refineries of this character now exist in London, Hamburg, Frankfort, Pforzheim, Philadelphia, Perth Amboy, and at one place in France. The Moebius process of refining silver, is in use by Johnson & Sons in London, at Hamburg, and at Perth Amboy, in America. The Gutzkow or Rössler process, is worked at the Frankfort Refinery of the Deutsche Gold und Silber Scheideanstalt, while at Pforzheim, the Dietzel process is employed. The latter process depends upon the use of a solution of copper nitrate in place of the silver nitrate used in the Moebius process. This electrolyte deposits copper at the cathode and dissolves copper and silver at the anode. When the silver in solution has reached a certain degree of concentration, the electrolyte is removed from the vat and the silver is displaced chemically by means of copper filings, or sheet cuttings. Special treatment is required to remove the other impurities, and the acidified solution of copper nitrate is then returned to the depositing vats for electrolysis with new anodes. Using silver-copper alloys as anode material, the value of the recovered copper in some cases is said to cover all the costs of the process.

The Wohlwill process for separating gold-silver alloys, is in use at Hamburg, in France, and in Philadelphia, Pa. The process is covered by the English Patent No. 7,783 of 1896, and is based upon the employment of an acid solution of auric chloride as electrolyte, with anodes of gold-silver alloys, assaying 0·850 fine of gold. A current density of from 1,000 to 2,000 amperes per sq. m. of anode surface is required, with a temperature of from 60° to 70°C.

A refinery for the treatment of gold and silver bullion, is reported to have been

[8] MINERAL INDUSTRY, Vol. IX., p. 608.

erected by the Deutsche Gold und Silber Scheideanstalt in Sweden, but particulars concerning it are not yet published.

No separate figures for the output of the European refineries can be given for 1901, but in 1900 the Frankfort refinery was reported to have produced 261,312 oz. gold, and 7,186,080 oz. silver. The combined value of the precious metals recovered by the Hamburg and Frankfort refineries in the same year is estimated to have amounted to $12,000,000.

CARBORUNDUM.—The manufacture of this product (silicon-carbide) is carried on under the Acheson patents at Niagara Falls, N. Y., and at several small works in Europe. The latter, however, have mainly been erected to protect the patent rights in those countries which demand local operation of the protected process, and the Niagara works practically controls the output. In 1901, the production at Niagara Falls amounted to 1,741 metric tons, as compared with 1,089 tons in 1900. Over 2,000 H.P. are now being utilized in the manufacture. During 1901 the carborundum company increased its capital to $1,000,000. The European works are situated at La Bathie, France; Iserlohn, Germany, and Prague, Austria.

CHLORATES.—(See the detailed report on page 589 of this volume.)

COPPER.—The appendix to the presidential address delivered by Swan before the Society of Chemical Industry at Glasgow in July, 1901, contained some interesting facts relative to the present position of the electrolytic copper industry in Europe. A circular letter and form had been sent out to the 29 refineries supposed to be operating in Europe, but of these only 11 had replied to the inquiry. The information obtained is reprinted in Table I. below; the letter N in the three

Name of Firm.	Locality.	Source of Power.	Horse Power.		Output in 1900. Tons.
			Available	Utilized.	
Mansfeldische Gewerkschaft	Eisleben	Steam and gas	100	N	N
Bergbau u. Eisenhütten Gewerkschaft	Wittkowitz	Steam	10	10	180
Elliott's Metal Company	Pembrey	Steam	600	(?)	N
Allg. Elektro-metallurgische Gesellschaft	Papenburg	Steam	N	N	(?)
T. Bolton & Sons	Oakamoor	Steam	(?)	(?)	N
Etablissements Industriels. E. C. Gramont	Pont de-Cheruy	Water	150	50	150
English Electro-metallurgical Co	Hunslet	Steam	N	(?)	(?)
Königliches Hüttenamt	Oker	Water and steam	N	N	N
Elmore's Metall-Akt. Gesell	Schladern	Water and steam	500, 360	350	1,200
Königliche Hütten-verwaltung	Brixlegg	Water	N	N	N
Nord-deutsche Affinerie	Hamburg	Steam	N	N	N
Elektro-Metall-Werk Nikolajeff	Moscow	Steam	60	35	350

last columns denoting that figures were received, but not for separate publication. The aggregate production of nine refineries in 1900 amounted to 18,962 tons of copper, and Swan estimates that the total European production of electrolytically refined copper is now less than 37,000 tons per annum. Most of the German, Austrian, and Russian refineries are working on a very small scale, and many appear to be dependent upon local mines for their supply of raw copper. As an example of the smallness of some of the European refineries, the annual production at Wittkowitz, Austria, of 180 tons; at Pont-de-Cheruy in France, of 150 tons, and at Besztercyebanya, Hungary, of 106 tons, may be noted. The growth of the electrolytic refining industry in America and the practical monopoly of the supplies of copper best suited for the electrolytic process which these refineries enjoy, has hindered further development of the industry in Europe.

The refineries at Swansea and at Pembrey in South Wales, and at Hamburg, all of which formerly had no difficulty in obtaining a sufficient amount of raw copper, are now handicapped by this absorption of American supplies and their output of refined copper has consequently diminished in recent years. Possibly the opening of new mines in Australia and Canada during the last two years will improve the position of European refineries.

The refining companies engaged in the manufacture of copper in tube and sheet form are operating with varying success. The parent English company, working the Elmore process at Hunslet, has changed its name and is now known as the English Metallurgical Co. It has been engaged in the usual litigation with subsidiary companies during 1901 and has paid no dividend to its patient and long-suffering shareholders. The plant at the Hunslet factory near Leeds has been overhauled, and the Secretary stated in December, 1901, that work would be resumed on a large scale in January, 1902. This company has suffered from three evils: overcapitalization, litigation and an incomplete process. The French and German Elmore companies with works at Dives and Schladern respectively, are more successful; the latter company had a striking exhibit at the Paris (1900) Exposition. The Schladern works produced 1,200 tons copper, chiefly as tubes, in 1900 and the demand for its product is growing. The French company is still more successful, and 7,000 tons of copper chiefly in tube form, was reported to have been sold in 1900. Its report for the year 1900 showed a gross profit of $221,000. The raw copper used in this refinery is obtained from Chile and Japan. Both of these foreign companies are said to work a modified form of the original Elmore process and the tubes are drawn down, after deposition. At Schladern, according to Haber,[9] a current of 250 amperes per sq. m. is used, with an E.M.F. of only 0·70 volts. With regard to the Dumoulin process, in which strips of skin replace the agate burnishers, the directors of the Electrical Copper Co., operating this process at Widnes, Lancashire, have decided to sell the plant and patents. At the fifth annual meeting, held in London on December 27, 1901, it was stated that the failure to earn profits at Widnes had been due to three causes—namely: small output, high price of fuel, and heavy interest on loans. The Widnes works were shut down in July, 1901, and are not to be restarted. As the enormous sum of £405,000 in cash and shares was paid by this company for the Dumoulin patents, overcapitalization might well have been included by the directors as a fourth cause of failure.

The Cowper-Coles centrifugal process, in which the skin friction of the electrolyte supplies the place of agate burnishers and strips of skin, was reported to be about to receive industrial trial in January, 1901, but no details of this trial have yet been published. The Hoepfner extraction process is operated at Papenburg, Germany. The ore is leached with a hot cupric chloride solution, and the iron, nickel, lead, and silver, are separated by a combined chemical and electrolytic treatment. It is reported that ores containing 3·5% Cu are being employed, and that a current efficiency of 90% is being attained with an E.M.F. of 0·80 volt. Although this process was previously tried at Giessen and Wildenau with poor results, better success has attended the Papenburg experiment, and 1 E.H.P.-day

[9] *Zeitschrift fuer Angewandte Chemie*, Feb. 26, 1901.

of 24 hours is said to be yielding 54 kg. copper. The chief difficulty is to prevent the deposited copper from being redissolved in the electrolyte.

A recent United States consular report gives some interesting historical details relating to the Siemens & Halske copper extraction process, in which ferric sulphate was used as leaching agent, a diaphragm being employed to separate the anode and cathode compartments of the cell. The process was patented in 1886 and tried at Geneva in 1890, and at Stolberg about 1893. Both plants failed, probably owing to excessive cost of maintaining the diaphragms. Without diaphragms, the copper cathode dissolved in the ferric sulphate as it re-formed at the anode. It is therefore probable that the history of the Marchese and Siemens & Halske processes may be repeated in that of the Hoepfner copper extraction process, in connection with the working of which, the same difficulty is reported to have arisen.

The growth and progress of the electrolytic refining industry in America, have been dealt with elsewhere in this volume (see p. 218). The disastrous collapse of the "Amalgamated Copper Company's" control of the market and price has also been referred to at length, and its effects on the collateral industries described. The effect of the striking fall in price, upon the new mining companies, floated in London in 1900 and 1901, has however not been specially dealt with. It must be first pointed out, that the collapse has been practically due to the increased production of mines outside the control of the Amalgamated Copper Co. in America, and the Rio Tinto Co. in Europe. The effect of the increased price at which copper was sold in 1899 and 1900 called into existence a large number of new mining companies, having as their object either the re-opening of old mines or the exploitation of new ones. In this connection it may be of interest to give details of the copper mining company flotations in London during 1899 and 1900. The figures are presented in tabular form in Table II.

TABLE II.—NEW COPPER MINING COMPANIES—FLOATED IN LONDON 1899-1900.

No.	Name of Company.	Locality of Mines.	Capital.	Date of Flotation.	Remarks.
1	Le Roi Mining Co.	B. Columbia.	$4,800,000	December..1898	.....
2	Copper Corporation of Chile.	Chile.	960,000	December..1898	Old mines.
3	Mid Moonta Copper Mines	S. Australia	624,000	December..1898	.....
4	Mount Lyall Comstock Copper Co.	Tasmania.	2,400,000	January...1899	.....
5	Copper King, Ltd.	California.	1,700,000	January...1899	.....
6	Balla Balla Copper Mines, Ltd.	Australia, N. W.	1,200,000	February ..1899	Old mines.
7	Colonial Copper Corporation.	New South Wales.	600,000	April 1899	Old mines.
8	Einasleigh Freehold Copper Mine.	Queensland.	960,000	May.....1899	.....
9	Tablas Finana Copper Co.	Spain	720,000	May.....1899	Old mines.
10	Panuco Copper Co. (in liquidation).	Mexico	2,400 000	May.....1899	.....
11	The Lloyd Copper Co.	New South Wales.	1,200,000	May.....1899	Old mines.
12	Copper Company of British Columbia.	B. Columbia.	480,000	July 1899	.....
13	Ardilla Copper Mines.	Portugal.	576,000	May.....1899	.....
14	Mount Lyall Blocks Copper Corporation.	Tasmania.	1,440,000	August....1899	.....
15	Caledonia Copper Co.	New Caledonia.	3,600,000	August....1899	.....
16	Mount Chalmers Copper Mines, Ltd.	Queensland.	720,000	August....1899	.....
17	Le Roi (No. 2, Ltd.) Copper Mines.	B. Columbia.	2,880,000	June.....1900	.....
18	Velvet (Rossland) Mine, Ltd.	B. Columbia.	960,000	June.....1900	.....
19	Rossland & Great Western Mines, Ltd.	B. Columbia.	2,400,000	July. 1900	.....
20	Wandilta Copper Mines, Ltd.	Australia (?).	576,000	December.1900	.....
	Total	.....	$31,196,000	.....	.....

That the properties of which these companies gained possession, contained workable copper ores is no doubt true; but estimates of profit based on G. M. B.s selling at £70@£75 per ton, are apt to be falsified when the price has fallen to

£48, and unless the value of copper speedily returns to its former level, the financial prospect for many of these new mining companies will be far from rosy. It is not every copper mining company that is capitalized on the moderate basis of the Rio Tinto Co., which in 1900 paid its ordinary shareholders an 85% dividend. The tendency is for promoters to multiply the maximum estimated profit by ten in order to arrive at a fair (?) capital valuation, and when the maximum profits are based on copper at £74 per ton, the results of this system of finance may prove disastrous for the original investors.

FERROCHROME AND SIMILAR ALLOYS.—*Ferrochrome* is being produced by the Willson Aluminum Co. at a new factory on the great Kanawha River, Va. Chrome ores from Asia Minor are used and an alternating current of 3,000 H.P. is employed in smelting these ores in the electric furnace. The ferrochrome produced contains 70% Cr and is used by the Carnegie and Bethlehem Steel companies in the manufacture of armor plates. The same alloy is made at Froges in France by the Société Electro-metallurgique Française; in this case also the electric furnace is used to smelt the ores. At Essen in Germany, ferrochrome alloys are made by the Goldschmidt process, in which powdered aluminum is used as the reducing and heat-producing agent. (See "Aluminum—Utilization," p. 23, this volume.) The ferrochrome alloy containing from 66 to 70% Cr, 30 to 34% Fe and less than 1% C, is said to be the best for use in steel-making as it melts rapidly. Chromium containing 96 to 98% metal made by the Goldschmidt process is not so useful, as it contains from 2 to 4% impurities—chiefly aluminum. The price of 66 to 70% ferrochrome in France is 1,000 fr. per ton, and of pure chromium 7·75 fr. per kg.; but overproduction in this industry is already reported.

Ferrosilicon is produced at Meran, by heating in an electric furnace 1,000 parts scrap iron, 410 parts quartz sand and 390 parts coke. The alloy contains 21·5% Si, and costs 200 fr. per ton. The yield is 0·2 kg. per K.W. hour.

Ferrotitanium is produced at Niagara Falls by heating scrap iron, titaniferous iron ore and aluminum in the resistance type of furnace; early in 1901, Dunlap reported that 500 lb. were being produced per 24 hours. Ferrotitanium containing 25% Ti and 0·40% C is sold in France at 10 fr. per kg.[10]

Silicon-copper is reported to be made by the Cowles Electric Smelting Co. at Lockport, N. J., and is employed as a deoxidizer in foundry work. No details of its manufacture are available for publication.

HYPOCHLORITES.—(See report under this title, elsewhere in this volume.)

IRON AND STEEL.—The possibility of smelting iron ores in the electric furnace has been proved by the experimental trials of the Stassano process at Rome in 1899 and a plant utilizing 1,500 H.P. has been erected at Darfo in northern Italy for the exploitation of this process on an industrial scale. The company possesses a capital of $172,000 and it is expected that iron will be produced at a cost of 100 fr. per ton, as compared with 160 fr. per ton by the ordinary smelting methods employed in Italy. The works is designed for an output of 4,000 tons

[10] A detailed description of the manufacture of titanium and its alloys is given in THE MINERAL INDUSTRY, Vol. IX., pp. 715-720.

of iron per year and ores from the mines in the Bergamosca Alps will be used. Goldschmidt, after inspecting the smelting furnaces in operation at Darfo on June 19, 1901, has reported favorably on the prospects of this process. Other experimental trials of the electric furnace for the reduction of iron ores have been carried out at Prague in Austria, at Le Praz in France and at the Güsingen foundry in Sweden. The latter works is said to be producing 1,200 kg. steel per day by the Kjellin process and a large installation of smelting furnaces in conjunction with a power station at Dalef is now planned. The erection of an electric smelting works for dealing with the hematite ores of the Bernese Oberland is also projected at Meiringen, in Switzerland; power from the river Aar is to be utilized in this undertaking. Detailed figures for the experimental trials have been published only in the case of the Stassano process, and after submitting these to a close examination,[11] it appears that the electric-furnace methods of iron and steel production can only succeed in localities where coal and coke are abnormally high in cost, and in countries having heavy protective duties on iron and steel.

LEAD AND ITS COMPOUNDS.—The Electrical Lead Reduction Co., at Niagara Falls, N. Y., with a capital of $12,000,000, operates with 600 H.P. Galena is the raw material of the process and is reduced in the electrolytic cells to spongy lead, the sulphur being eliminated as H_2S. This gas is burned to yield sulphuric acid and the lead is converted into 99% litharge for use in the manufacture of rubber and for accumulators. The present capacity of the works is 10 tons spongy lead per day. The manufacture is reported to be successful, the works have been enlarged after a fire in 1900.

MISCELLANEOUS PRODUCTS.—*Ammonium Persulphate and Potassium Permanganate* are produced by electrolytic methods at St. Michel, France, by the Société d'Electrochimie. The former salt is much used for bleaching purposes, and in photography.

Antimony is being extracted from its ores by an electrolytic method at Banya, Hungary, but it has not been possible to obtain any details of the process used.

Arsenic.—The Arsenical Ore Reduction Co. at Newark, N. J., is about to operate the Westman electric furnace method of treating these ores. Rich mispickel from Ontario is to be employed and in the preliminary trials with this ore, 1·27-K.W. hours were said to suffice for smelting 1 ton of ore. All the sulphur in the ore combines with the iron and the arsenic distils over in the gaseous state.

Artificial Graphite[12] is produced in increasing quantity in the electric furnace under the Acheson patents by the International Acheson Graphite Co. at Niagara Falls. The method depends upon heating amorphous carbon in presence of ferric oxide, to a very high temperature; the iron is volatilized during the process and the carbon is graphitized. European factories for carrying on the same manufacture exist at La Bathie in France and at Benetek in Hungary. At Chedde and at N. de Briancon in France, graphitized carbon for electrodes is also

[11] *The Electrical Review* (London), June 15, 1900.

[12] Further details of this process are given elsewhere in this volume, under the caption "Graphite."

produced by Messrs. Corbin et Cie. and by the Société des Carbures Metalliques of Paris.

Glass Making.—One of the latest proposals for use of the electric furnace is in glass making, and several forms of furnace for this purpose have been patented and are now undergoing trial. Full details of the experiments with the Becker furnace at Cologne, Germany, will be found in the paper named below.[13] At present this application of electricity is of little economic importance. Where fuel is cheap, the regenerative gas furnace, used in all up-to-date glass works, is a form of heating apparatus of striking efficiency.

Magnesium.—This metal is produced by the Elektron Co. at Griesheim by the electrolysis of fused carnallite, the method and apparatus resembling that employed for the electrolytic production of sodium. The manufacture was originally in the hands of a company operating at Hemelingen, Germany, but it has not been possible to learn whether this company is still producing the metal.

Molybdenum and Tungsten.—These rare metals are produced in Paris by a company named La Neo-Metallurgie, but beyond the fact that the methods used are those which were employed by Moissan in his classical researches with the electric furnace, no details of the company's operations have been published.

Metals, Cleaning and Scouring the Surface of.—A large number of processes have been patented for cleaning metal surfaces by aid of electrolysis. In some cases a solution of sodium hydrate is employed as electrolyte and the direction of the current is frequently reversed in order to obtain both oxidizing and reducing actions at the metal surface. The Verein Elektricitäts Aktien Gesellschaft of Vienna has brought out an improved method of cleaning steel sheets in which a solution of sodium sulphate is used as electrolyte, the sheets being used as anodes, with carbon or platinum cathodes. Secondary chemical action causes precipitation of the dissolved metal and regeneration of the electrolyte. No direct statements have been obtained as to the actual operation of these processes in Europe, but they are undoubtedly of value for special purposes.

Tanning.—Electric methods of tanning make slow progress, although these methods have been in actual use for some years in two tanning factories, one in Switzerland and one in Sweden. The Groth process is in operation at Wem, in Shropshire, England, and at Wenersborg in Sweden. At the first named place the plant has a capacity of 750 hides per week, and in May, 1901, Dr. Groth stated that his process was about to be adopted by three leading tanneries, in Germany, Austria and Russia respectively. The time required to tan hides is much reduced by the Groth process which combines mechanical movement of the hides in the tan-pit with electrolytic action; but doubts have been expressed as to the durability of the leather produced.

Tin.—Numerous electrolytic processes have been patented and tried on an industrial scale for the recovery of tin from the tin-scrap which abounds in the dust heaps of all large cities. The processes work satisfactorily and the only difficulty appears to be to insure a sufficient supply of the raw material at a reasonable cost. Several works of this character are reported to exist in Ger-

[13] *Electrochemische Zeitschrift*, September, 1901.

many, the most important of these being at Essen, where from 50 to 60 tons scrap are treated daily by the Goldschmidt process.[14] During 1901 a company for this purpose was registered in London with a capital of $48,000 and a plant for the treatment of 50 tons cuttings per month, was to be erected presumably in London. The process to be used was a patented one and was reported to have been tried with success on a commercial scale, but no names or other details were given.

Wood-Seasoning.—The use of electrolytic methods in wood seasoning dates from 1898, when the Société Anonyme pour la Senilisation des Bois was registered in Paris with a capital of $230,000 for operating the Nodon & Bretonnau method. This method is based upon the immersion of half the timber in a tank of liquid, and the use of electrolytic action to drive out the sap and to impregnate the wood with a sodium boro-resinate solution. The timber requires from 5 to 8 hours' treatment in the electrolytic bath and from 3 to 6 weeks for drying. This represents one-sixth of the time at present required. The English rights for this process have been sold to the Electric Timber Seasoning & Preservation Co. registered in 1899 with a capital of $720,000, and a plant has been installed and operated at Charlton in Kent. Both the French and English companies appear to be overcapitalized and the financial success of this process is somewhat doubtful, excepting when applied to wood required for special purposes.

NICKEL.—The chief event in Europe during 1901 in connection with the nickel industry has been the flotation of the Mond Nickel Co. with a capital of $2,880,000, for purchase of the Mond patents relating to nickel extraction, and for erection of a large works for operating the process at Clydach in Wales. Although the Mond process is not an electrolytic one, this flotation demands notice because it is proposed to work at Clydach on a large scale, and an output is contemplated of from 1,000 to 1,500 tons nickel per annum (equal to one-sixth of the present world production). The Sudbury ore will be used in this works, and several mining properties in that region are included in the purchase price of $1,560,000, paid to Dr. Mond for the patents and properties, handed over to the new company. The Mond process depends upon the property of carbonic oxide gas to carry off nickel in the gaseous state (as nickel-carbonyl) when passed over the metal in a finely divided metallic state. Full details of the process and plant required for operating it, will be found in the journal named below.[15]

The Hoepfner extraction process is still operated at Papenburg, Germany, by the Allgemeine Elektro-Metallurgischen Gesellschaft. New Caledonian ore is employed as raw material, and a mixed solution of cupric and calcium chlorides is used for leaching. The early decease of Dr. Hoepfner at Denver, Colo., in December, 1900, has removed the inventor of this process at the moment when his guidance and help were most required. Early trials of this process at Wiedenau near Siegen, in 1893 had ended in failure and modifications in the original process had been introduced at Papenburg. In July, 1901, it was reported that this works was producing 1 ton nickel per day.

[14] *Zeitschrift fuer Elektrochemie*, Jan. 9, 1902.

[15] *Proceedings of the Institution of Civil Engineers*, Vol. for 1898.

New deposits of nickel ore are reported to have been discovered in New South Wales and a syndicate of capitalists has been formed to exploit this field. A nickel smelting and refining works is to be established at Newcastle, N. S. W., but it is stated that this works will draw its supplies of ore from New Caledonia. At present the New Caledonian mines are producing 120,000 tons ore per annum, the greater portion of which is shipped to the Tyne and smelted at Glasgow, while the raw nickel is refined at Havre. A movement is on foot to establish smelters in New Caledonia but it is doubtful whether this will succeed, as State aid would be required to compensate for the high cost of fuel.

Le Verrier proposes to extract nickel from nickel ores, by using them as anode material in an electrolyte composed of a 10% solution of nickel, ammonium and sodium chlorides. An occasional addition of sodium hypochlorite is made to oxidize and precipitate the iron, as $Fe_2(OH)_6$, but excess must be avoided. The sulphate salts of nickel and ammonium may also be used in place of the chlorides. The electrolyte must be freely circulated in the bath and it must be withdrawn and filtered at frequent intervals. The bath must be kept neutral or slightly alkaline. A current density of 100 amperes per sq. m. of cathode surface, and an E.M.F. of 2 volts, are found to yield the best results. A higher current density leads to the formation of Ni_3O_4 at the cathode. If copper be present, it is deposited with the nickel but a separation can be effected by employing a high current density with an excess of sodium hypochlorite in the electrolyte; nickel and tin are then precipitated as oxides, while the copper is deposited at the cathode. Sulphur in moderate amounts does not interfere with the method as it remains insoluble, and can be removed by filtration. The German patent covering this method is No. 5,781, of 1899. In some respects it resembles the Storer process, although in the latter, the powdered ore was heated with ferric chloride in a closed vessel at 190°C. for several hours, and the resultant solution was filtered from the $Fe_2(OH)_6$, before electrolysis. As far as it is generally known neither process has yet received industrial trial.

With regard to the electro-deposition of nickel, Pfanhauser has stated that he has worked out a method which permits thick deposits to be obtained in one-twentieth of the time required by the older methods, the deposits being homogeneous, malleable and equal in physical characteristics to plates obtained by smelting and rolling. For articles requiring only a thin coating of nickel, from 2 to 3 minutes in the improved electrolyte bath is said to suffice. No details of the method have however been given.[16] Kugel proposes to obtain thick plates of nickel by using an acid bath at a temperature of 30°C. or over, the acid being one that is not decomposed by the current.[17]

As regards the use of nickel for the manufacture of nickel steel, Porter has published tests showing that forgings of nickel steel containing from 3 to 3·5% Ni and 0·28% C have a tensile strength 40% higher than steels of the same carbon contents without the nickel. The nickel steels are also less corrodible in salt water. Wilson has published results of physical tests made with nickel-manganese steel containing 25% Ni, 5% Mn and 0·81% C. The specified resist-

[16] *Elektrochemische Zeitschrift*, January, 1901. [17] English Patent No. 2,994, of 1901.

ance of this steel, is four and a half times greater than that of the German-silver alloy usually employed for resistance coils, and its use is recommended for this purpose. The future of nickel steel in the arts and industries depends largely upon the cheapening of the methods of nickel extraction, and in this connection the new Mond works at Clydach in South Wales and the new extraction works at Sault Ste. Marie in Canada are likely to have important effects upon the industry.

At the Glasgow (1901) Exhibition, the Orford Copper Co. exhibited specimens of electrolytic nickel which analyzed 99·25% Ni. Tests of pure malleable nickel made by this company, showed tensile strengths ranging from 100,000 to 160,000 lb. per sq. in.

ORGANIC PRODUCTS.—Details relative to the industrial use of electrolysis in the manufacture of organic products are exceedingly difficult to obtain, for the companies engaged in these manufactures preserve great secrecy as to their methods. A large amount of laboratory work has however been carried out during the last few years and it would seem probable that some of these methods have been adopted for permanent industrial use.

Iodoform, Chloral, Azo- and Hydrazo-Compounds have been produced by electrolytic methods and while lacking direct confirmation it is believed that all of these substances are now being manufactured industrially by the new methods. Messrs. Schering of Berlin, the Badische Anilin und Soda Fabrik, Meister Lucius & Brüning, and the Farben-fabrik vorm. Fred Bayer & Co. are the pioneer companies in this field. Perhaps the most direct proof that electrolytic methods are being used is the fact that the Höchst-am-Main color works of Meister Lucius & Brüning are employing 3,000 K.W. continuous current, transmitted to their works by an underground cable from the new generating station. Continuous current is not generally used for motors in Germany, and although a portion of this current is utilized for sodium manufacture (see below), it is unlikely that the whole 3,000 K.W. is employed in this way.

In the United Kingdom, cyanides have been produced by an electric furnace method under the Readman patents, and the inventor stated in 1898, that the patents had been sold to the Scottish Cyanide Co. and that Works were to be built for operating the process at Leven in Fifeshire. Since that date no further details have been made public concerning the company, or its projected Works.

In France electricity is used in the production of heliotropine and vanillin at Courbevoie near Paris. The method is based upon the oxidation of oil of cloves. The Verley ozonizer is employed, and 10,000 kg. of the two compounds are reported to be produced annually. A secondary use of electrolysis in color manufacture is reported from Germany. Chromic acid is one of the most usual oxidizing agents in organic work and the renewal of the spent chromic acid solutions by chemical means is troublesome and expensive. Meister Lucius & Brüning have therefore adopted an electrolytic method for reoxidizing these solutions, which has given very satisfactory results.[18]

OXYGEN AND HYDROGEN.—The production of oxygen and hydrogen gases by

[18] *Chemiker-Zeitung*, Oct. 27, 1900.

the electrolysis of water, has become one of the minor branches of electrochemical industry, and works for this manufacture, are now reported to be in operation at Tivoli, Rome, Milan, Zurich, Lucerne, Hanau, Brussels, Toulouse and Montbard. In some cases the gases are used on the spot—(at Rome for inflating military balloons, and at Hanau for melting platinum)—but in the majority of instances the gases are compressed by special pumps and are sold in the usual form of pressure cylinders. Many different forms of decomposing cell have been patented and are in actual use. The majority utilize a solution of sodium hydrate as electrolyte and iron or nickel as the metal for the cell structure and electrodes. In the Schoop apparatus however dilute sulphuric acid is used as electrolyte and the walls of the cell and electrodes are of lead. At Hanau, the Schuckert cell is in use; and a current of 200 amperes and 2·75 volts is employed to decompose the caustic soda solution. Power equal to 60 K.W. per 24 hours is said to produce 100 cu. m. oxygen and 200 cu. m. hydrogen. The daily running expenses of the plant are stated to be $31·20. At Brussels, the Société l'Oxyhydrique work the Garuti cell and process. In this case also sodium hydrate is the electrolyte, and 12·2-K.W. hours are said to yield 1 cu. m. oxygen and 2 cu. m. hydrogen. The Garuti apparatus is used also at Tivoli near Rome, and at Lucerne. With electric power at ·2c. per K.W. hour, the cost of 1 cu. m. oxygen, and 2 cu. m. hydrogen is stated to be only 2·5 cents.

At Oloron Ste. Marie, in the Pyrenees, a similar form of apparatus has been in use since 1898, and 12·5-K.W. hours are required to yield 1 cu. m. oxygen and the corresponding volume of hydrogen. The cost of the H.P. year at this place, is reported to be only $10·80.

In England, the War Office has established a plant at Aldershot for the production of hydrogen gas—the gas being used for inflating military balloons—and one ampere hour is said to yield 5 l. hydrogen and 2·5 l. of oxygen gas. Both gases are compressed and stored in cylinders until required for use.

In America, electrolytic installations for the production of oxygen and hydrogen gases have been erected in the laboratories of Iowa State College, and of Lehigh University. Caustic soda is used in these cases as electrolyte and cast iron for the electrodes. With current at 2c. per K.W. hour, 1 cu. ft. oxygen gas and 2 cu. ft. hydrogen gas, cost one cent.

Ozone.—There is little to report with regard to new developments in the ozone industry, during 1901. The elaborate exhibit of the Société Industrielle de l'Ozone at the Paris 1900 Exposition has however revived to a certain extent the interest in ozone as an agent for water purification. The exhibit at Paris consisted of a full size working model of the Marmier & Abraham apparatus as used at Lille. Alternating current generated at 2,100 volts was transformed into current at 40,000 volts. The electrodes of the ozonizer were of cast iron cooled by water and were separated by two glass plates 2 m. square, and 7 mm. thick, forming the air channel. The distance separating the glass plates was only 2 mm. The air passed in at the edges of the plates and was drawn away at the center. A special device was required to prevent the current being "earthed" by the water used for cooling the electrodes. The water before treatment with

the ozone is subjected to filtration. The cost of the treatment is stated by the inventors to be 0·0045 fr. per cu. m., or 2·5c. per 1,000 cu. ft. The installation at Lille which was made in 1898, is said to be giving satisfactory results. The Marmier & Abraham apparatus is reported to be in use also at Boleo, in Mexico, but no details of this installation have been published. With regard to the practical operation of this system, Abraham read a paper in November, 1900, before the Société Internationale des Electriciens, in which he emphasized the following points:—

1. 8 to 10 mg. ozone, per liter of air or gas, must be present.

2. The duration of contact between the water and ozonized air, must be sufficient to effect sterilization.

3. The contact must be molecular, for ozone is insoluble in water.

A Gay-Lussac tower packed with flints, is found to fulfil the conditions 2 and *3*. This paper is provided with diagrams of the installation at Lille, and readers desiring to consult these, are referred to the volume named below.[19]

Otto has studied the application of ozone to water purification, and has published an interesting memoir upon this subject.[20] He uses in place of the Gay-Lussac absorbing tower packed with flints, a tower filled with trays, and the water and ozonized air are forced into this tower by a cone-shaped injector as spray. The molecular contact between the ozone and the water prescribed by Abraham as necessary to effect purification, would doubtless be more efficiently attained by this apparatus than by a simple flint-packed tower, but no statements have appeared that Otto's form of absorbing-tower has yet received trial upon a large scale. A similar system of mixing the ozonized air with the liquid requiring purification was used in London in 1899, during the trials made with ozone for refining oils and fats, and the principle of the method is undoubtedly right.

Details have recently been published relating to the experimental plant for water sterilization by the Siemens & Halske system erected at Berlin in 1898.[21] This plant was designed to treat 240 cu. m. of water per 24 hours, and comprised ozonizers of the Siemens & Halske type, sterilizing tower, sand filters, and the necessary pumps and storage tanks. Ozonizers of both the plate and tube type have been used and a yield of from 20 to 25 g. ozone per E.H.P. hour with a concentration of 2·5 g. ozone per cu. m. of air are said to have been obtained. The cost per 1,000 cu. ft. of water is 11·8c., of which total, three-fifths represent the cost of electrical energy. This is a much higher cost than that given by Abraham.

The number of bacteriological organisms at Berlin have been reduced from 600,000 to 10 per cu. m. by the combined sand filtration and ozone treatment, water from the river Spree being used in the trials. The capital outlay upon a plant of 3,600 cu. m. per day capacity is estimated to amount to $32,400, of which $14,400 represent the plant necessary for an ordinary waterworks and $18,000 the expenditure upon the electrical and ozone-producing apparatus.

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[19] *Bulletin de la Société Internationale des Electriciens*, November, 1900.
[20] *Memoirs de la Société Ingenieur Civil de France*, February, 1900.
[21] *Elektrochemische Zeitschrift*, Nov. 14, 1901.

The water authorities of Moscow are reported to be using ozone for the treatment of their water supply, but no details of this installation beyond the cost, which is said to be $6·25 per million gallons or 3·9c. per 1,000 cu. ft., are yet forthcoming. One of the London water companies also, is reported to be experimenting in the same direction.

With regard to other uses of ozone, or ozonized air, little progress has been made during 1901. The German firm of Baeyer, in a recent patent, proposes to use ozone for the production of permanganates from manganates, and Siemens & Halske have proposed its use in conjunction with ferric oxide for clearing turbid liquids. At Courbevoie near Paris, 150 to 300 H.P. are employed for generating ozone in connection with the manufacture of organic products, the Verley ozonizer being used.

Chassy has contributed a paper to the French Academie des Sciences on the theory of ozone-production by the electro-static discharge.[22] Experimenting with pure oxygen in place of air and using the Berthelot type of ozonizer, he found that the quantity of ozone produced tends toward a limit determined by the temperature. To obtain a concentration of 7% requires the expenditure of 90 times as much electrical energy as for a concentration of 0·5%. This research therefore indicates that, as in many electrolytic processes, high current and energy efficiency cannot be united with the production of a concentrated form of the compound resulting from the electro-static action. Electro-static discharge not only produces ozone, but also decomposes that already formed and a point is quickly reached where production and decomposition almost balance each other.

PHOSPHORUS.—The manufacture of phosphorus by the electro-thermal method has been carried on at Paris, Griesheim, Vernier, Wednesfield near Birmingham, and at Niagara; and these works are believed to be still in operation. Phosphorus manufacturers are however unusually secretive concerning their progress (or the reverse), and nothing can be gleaned from them by direct application. The Readman process (English Patent No. 18,785 of 1895) is used at Birmingham and at Niagara Falls; the Frank & Hilbert process (patented, 1895) at Vernier, and the Billaudot process (patented, 1896) at Paris. The last named process was described by Borchers in THE MINERAL INDUSTRY, Vol. VIII., and no further details of it have since been published. The Frank & Hilbert process resembles it, since carbide production is combined with that of phosphorus. As regards the output of phosphorus by the works named above, no reliable figures can be obtained, but it has been estimated that over one-half of the phosphorus production of the world is now manufactured by the electric furnace method. The industry is however somewhat unsettled, owing to the decreasing use of white phosphorus in the manufacture of matches, and the more or less successful attempts to substitute less poisonous substances for it. Thus in France, a match known as the "S. & C." match is manufactured with a non-poisonous composition containing phosphorus sesquisulphide and potassium chlorate. According to Guillet,[23] the world consumption of phosphorus in 1900, amounted to 1,000,000 kg., of which France accounted for 30,000 kg. In 1899,

[22] *Comptes Rendus*, Vol. XX., p 789. [23] *Le Genie Civil*, July 14, 1900.

Germany imported 370,000 kg. phosphorus and exported 123,000 kg. Two-thirds of the imported phosphorus came from the United Kingdom. The German consumption is estimated to lie between 200,000 and 250,000 kg. per annum. The only exhibit of German phosphorus at the Paris (1900) Exposition was made by the Griesheim firm "Elektron."

In America beside the company working at Niagara Falls, a company has been formed to operate the extraction process worked out and patented by Dr. Machalske, of Long Island City, N. Y. The process is an electro-metallurgical one and with electric-power, at 3c. per E.H.P. hour the cost of yellow phosphorus is said to amount to only 7c. per lb.

SODIUM AND SODIUM PEROXIDE.—The number of factories producing sodium by the electrolytic method has been increased by one during 1900, the unsuccessful electrolytic alkali works at Les Clavaux, France, having been converted into a factory for the production of sodium and its higher oxides. From official information 2,000 H.P. is already being utilized at this place in the manufacture of sodium peroxide and a new compound called "Oxylithe." Castner's process is in use at Les Clavaux. The manufacture is under the control of the Société d'Electrochimie of Paris, which owns the French patents for the Castner process; and also the Gaubert patents for "Oxylithe." The latter is a mixture of sodium peroxide and potassium permanganate produced under pressure. When treated with water, this compound evolves oxygen gas. Important sales are expected for this new substance. A process has also been worked out by Hulin for obtaining pure oxygenated-water from sodium peroxide and it is proposed to use this solution, which contains no soda compounds, in fine bleaching work. Patents have been applied for. Sodium is also reported to be produced in France at Bellegarde, by the Becker process. A fused mixture of sodium hydrate and sodium carbonate is used as electrolyte, and a cone-shaped cover fixed with its lower edges dipping in the electrolyte is kept negatively charged in order to prevent oxidation of the sodium floating on the surface of the molten mass. A current of 1,500 amperes was stated to have been in use at Bellegarde in May, 1900, for the manufacture of sodium and magnesium, but recent confirmation of this statement is lacking.

In Germany, sodium is produced by the Castner process at Rheinfelden, the parent English company, and the Bitterfeld Elektro-Chemische Werke being financially interested in this works. Manufacture was commenced in 1899, but no details of the plant, or its output, are available for publication. The Castner cell and process are operated also at the Farbe-Werke of Meister Lucius & Brüning at Höchst-am-Main, but in this case the sodium produced is used entirely in the color works. The plant, which has been running since 1898, is reported to be of 150 H.P. capacity. The Neuhausen Aluminum Co. also is reported to be producing sodium by an unpatented process, but no details of the process or plant have been published.

In England, the manufacture was originally in the hands of the Aluminum Co. of Oldbury—where the Castner process was developed. This company is now absorbed by the Castner-Kellner Alkali Co. and the manufacture has been

transferred to the large works at Weston Point, near Runcorn. The sum paid for the assets of the Oldbury Company was $624,000, in shares of the Castner-Kellner Alkali Co. These assets include shares in the Rheinfelden and Niagara sub-companies promoted by the parent concern.

In America, the manufacture of sodium and its peroxide is carried on at Niagara by the Niagara Electro-Chemical Co., 400 H.P. being employed. The Castner cell and process are used and in 1900 the company was reported to be earning large profits. No figures are available for the output of sodium and sodium peroxide for the years 1900-1901. The South African war has temporarily injured the industry, since one of the chief outlets for sodium and its peroxide was in connection with the Rand gold-mining industry. The end of the war is therefore likely to be marked by a considerable increase in the output and profits of the works engaged in this manufacture.

ZINC.—The chief event of the past year in the zinc industry in Europe has been the financial collapse of the Smelting Corporation, which was formed to work the Fry process at Ellesmere Port near Manchester. This company was floated with a very large capital in 1898, and smelting works were erected at Ellesmere Port at a cost of $1,200,000. The zinc was obtained as zinc oxide and it was intended to recover the metal by an electrolytic fusion process but this portion of the process had not been developed when the collapse occurred. The plant was shut down in March, 1901 and the following causes of failure were given:—

(1) Failure of Mr. Fry to meet debenture engagements for $480,000. (2) Failure of the process to realize the early promises and reports. (3) Increased costs, due to the high price of fuel. (4) Litigation owing to fumes from the cupola furnaces. There is some talk of a reorganization of the company, and negotiations are now being conducted with that end in view.

The Ellerhausen process is another zinc extraction process operating in Europe, in which electrolysis plays only a secondary rôle. In this process, the ore is smelted at a high temperature, and the lead, zinc and silver, are volatilized. The metals are caught, by injecting cold water under pressure into the hot gases at the fans. Sulphides and oxides of lead, zinc, iron, arsenic and antimony are found as sludge, while zinc sulphate is obtained in solution. It has not been stated how the zinc is recovered from this solution but it is possible that electrolysis is employed. The Ellerhausen process is worked at Angoulême in France, by the British Sulphide Smelting Co. and, as the capital of this company is $3,840,000, it is not improbable that its financial future will be a troubled one.

A distillation process for the treatment of zinc ores, depending upon the use of the electric furnace in place of the usual cupola furnace, has been worked out and patented in Italy by Casaretti & Bertani. Very few details of this process have yet been made public, but it is stated that only 2-E.H.P. hours are required to produce 1 kg. zinc, and that 15 kg. coke are used as reducing agent for 100 kg. ore. The process is said to be worked by the Società Elettrici Metallurgice Lombarda, but official confirmation of this statement is lacking. The Sulphide Corporation of London also has introduced a new type of distillation process into its smelting works in New South Wales. In this case, zinc concentrates

form the raw material, and it is believed that ordinary cupola furnaces are employed. Details of the process however have not been published.

Distillation processes for dealing with complex zinc ores therefore seem to be in the ascendant, and where water power is available and coal scarce, such processes if successful will doubtless be operated in the future with electrical energy.

The Hoepfner process is in use by Brunner Mond & Co. at Winnington, England, and by the Erste Oesterreichische Soda Fabrik at Hruschau, Austria. This process is an electrolytic one and depends upon the use of the waste calcium chloride liquors from the ammonia soda works. A solution of zinc chloride is ultimately obtained which is electrolyzed with carbon anodes in a diaphragm cell. The chlorine obtained at the anode is used for bleach manufacture; and the zinc deposited at the cathode, of 99·95% purity, is sold for special purposes. The process was introduced at Winnington in 1897 and the plant is said to have been increased from its original 400 H.P. capacity, to 1,200 H.P.

The Swinburne-Ashcroft fusion process is about to be tried upon a somewhat extended scale at Weston Point, England, the earlier experimental plant at Milton in Staffordshire, having been dismantled and sold. In June, Ashcroft read a paper before the Institute of Mining and Metallurgy in London,[24] giving the results obtained in the trials at Milton and details of the improvements made in the process since the first patents were applied for. The process as now carried out consists of a cycle of operations, of which sulphur, silver, lead, zinc and chlorine are the final products. The pulverized unroasted ore is mixed with fused zinc chloride in a "converter," and chlorine gas is blown through the mass until all the metals have been converted into chlorides and the sulphur expelled. The fused mass is then decanted from the undecomposed residue and gangue and the silver removed by means of lead. The remaining mixture of fused lead and zinc chlorides is subjected to electrolysis after removal of the lead by the substitution of zinc. The inventors are hopeful of the ultimate success of this process upon which much time and money have been expended in the early trials.

A new electrolytic zinc extraction process invented by Strzoda is also reported to be in operation at Bockenheim, near Frankfort. An electrolyte of zinc sulphate and insoluble anodes are said to be employed, but beyond this details are lacking.

During 1900 and 1901, Lorenz has published the results of important researches bearing on the electrolysis of fused salts.[25] If H_2O be present, no zinc can be deposited from such fused mixtures, for hydrogen is liberated at the cathode in place of zinc. A treatment with hydrochloric acid, and evaporation, are necessary to remove the last traces of water. The later series of experiments dealt with the phenomena observed when fused lead chloride is the electrolyte.

The only new development to record with regard to electro-galvanizing is the erection of a plant for this work, at Gaarden, Germany, for the firm of Fred. Krupp.

[24] *Electrician*, July 12, 1901. [25] *Zeitschrift fuer Elektrochemie*, Nov. 15, 1900; July 4, 1901.

FELDSPAR.

THE production of feldspar for the past three years has steadily increased, the output in 1901 amounting to 34,741 long tons, valued at $220,422, as compared with 29,447 long tons, valued at $136,773 in 1900 and 26,968 tons ($137,886) in 1899. Of the product in 1901, 17·3% was ground by the producer, as compared with 84·1% in 1900. The chief sources of supply of feldspar were, as heretofore, Brandywine Summit, Embreeville and Chadds Ford, Pa., Bedford, N. Y., Branchville and South Glastonbury, Conn., Huntington, Mass., and Georgetown and Topsham, Me. The less important mines in Delaware, Virginia and South Carolina yielded a small amount. In 1901, however, Massachusetts reported no output.

For a detailed account of the occurrence, mining and uses of feldspar reference may be made to the article by T. C. Hopkins in THE MINERAL INDUSTRY, Vol. VII.

PRODUCTION OF FELDSPAR (CRUDE AND GROUND) IN THE UNITED STATES IN 1901.

State.	Crude.		Ground.	
	Quantity.	Value.	Quantity.	Value.
	Short Tons.		Short Tons.	
Connecticut	3,514	$4,902	7,275	$49,956
Maine	896	2,400	(a)	(a)
New York	1,060	1,000	3,344	20,000
Pennsylvania and Maryland	4,490	13,367	14,162	128,197
Totals	9,960	$21,669	24,781	$198,753

(a) Included with New York.

PRODUCTION OF FELDSPAR IN THE UNITED STATES IN 1898, 1899 AND 1900.

State.	1898.		1899.		1900.	
	Long Tons.	Value.	Long Tons.	Value.	Long Tons.	Value.
Connecticut	6,696	$37,944	11,104	$61,311	18,166	$68,873
Maine and Pennsylvania	12,954	58,953	14,644	71,755	14,481	65,901
Massachusetts	150	525	160	560	800	2,800
New York	1,550	9,725	1,060	4,240	1,000	4,200
Totals	21,350	$107,147	26,968	$137,866	29,447	$136,773

The price of feldspar ranges from $3 to $6 per long ton at the mine, according to quality, while the ground product of satisfactory grade brings about $7 per ton. For pottery uses it must be free from iron oxide, mica and quartz.

The commonest species of feldspar is orthoclase, or potash feldspar, which is the one generally used by potters in the United States. It is the most infusible member of the feldspar group, but thus far very little of the other species has been found in sufficient quantity and purity to mine. The attention of those searching for feldspar is directed to the large quantities of labradorite feldspar rock occurring in the Adirondack region, New York, which often contains very little iron oxide.

FLUORSPAR.

THE production of fluorspar in the United States continues to be derived chiefly from the mines in Crittendon and Livingston counties, Ky., and Hardin County, Ill., and in 1901 the quantity produced was 19,586 short tons, valued at $113,803, as compared with 21,656 short tons, valued at $113,430 in 1900, which indicates a decrease in production of 2,070 short tons, but of only $373 in value. Of the total production during 1901, 15,886 tons, valued at $79,783, was crude fluorspar, which was shipped in bulk. The quantity of ground fluorspar sold during the year was 3,700 tons, valued at $34,100. The statistics, as reported by the various companies engaged in this industry, indicate a larger quantity produced than was shipped, which can only be accounted for by the accumulation of stock at the mines. From other sources, however, it is authoritatively stated that very little stock is carried over at the end of each calendar year, as the season for hauling closes early in the fall and the accumulated stock on hand is rapidly depleted by the demand for the winter trade.

With the exception of the output from Rosiclaire, Ill., and a comparatively insignificant quantity mined on the Kentucky side of the Ohio river, near the mouth of the Cumberland river, all of the fluorspar mined in the district mentioned above is shipped by the Illinois Central Railroad. The producers of fluorite were the Kentucky Fluor Spar Co., the Fluorspar Co., Western Kentucky Mining Co., and Chicago Mining Co., all of Marion, Ky.; the Eagle Fluorspar Co., at Salem, Ky., and the Rosiclaire Lead & Fluorspar Mines at Rosiclaire, Ill. Early in 1902 the Kentucky Fluor Spar Co., which has been the chief producer of fluorspar in recent years, absorbed The Fluorspar Co., and is now by far the largest producer in Kentucky. This company and the Rosiclaire Lead & Fluorspar Mines produced nearly 80% of the total output during 1901.

A deposit of fluorspar has been reported in Yuma County, Ariz., containing veins from a few inches to 7 ft. or more in width. The crystals are of beautiful, characteristic colors—blue, green, red and purple—and should the demand for the use of fluorspar in smelting operations be greatly increased a market will be created for the Arizona mineral. Deposits of fluorspar have also been reported in Smith, Tousdale and Wilson counties, Tenn., and the Tennessee Fluorite & Mining Co. has been incorporated to work deposits near Bellwood, Smith County, Tenn. The deposits of fluorspar in Illinois and Kentucky are worked by shafts and drifts. The crude material is removed from the mine and generally concentrated by hand cobbing, machine or by water jigs, in some instances the product is shipped directly after washing, as it comes from the mine. It is interesting to note that valuable by-products are being saved. In addition to the fluorspar output the Rosiclaire Lead & Fluorspar mines produce galena, and the Chicago Mining Co., Kentucky Fluor Spar Co., and Western Fluorspar Co. produce zinc carbonate.

PRODUCTION OF FLUORSPAR IN THE UNITED STATES. (IN SHORT TONS.)

Year.	Tons.	Value.	Per Ton	Year.	Tons.	Value.	Per Ton	Year.	Tons.	Value.	Per Ton
1890....	8,250	$55,328	$6·70	1894.....	6,400	$38,400	$6·00	1898.....	12,145	$86,985	$7·16
1891....	6,320	38,000	6·00	1895.....	4,000	24,000	6·00	1899.....	24,080	152,655	6·35
1892....	9,000	54,000	6·00	1896.....	6,000	48,000	8·00	1900.....	21,656	113,490	5·24
1893....	9,700	63,050	6·50	1897	4,379	36,264	7·65	1901.....	19,586	113,803	5·81

For the American market fluorspar is divided into six grades, namely, American lump No. 1, American lump No. 2, gravel, crushed, ground fine, and ground extra fine. The foreign product appears in two grades only—lump and fine.

The prices for fluorspar per short ton during 1901 did not change materially from the quotations existing in 1900, *viz.*: Gravel spar, $5·26; lump spar, $5·50; and ground spar, $10, f. o. b. at mines. The average value of the fluorspar produced during 1901 was $5·81, as compared with $5·24 in 1900.

The imports of fluorspar into the United States are not separately classified by the Bureau of Statistics of the Treasury Department, the quantity imported being included among minerals and ores not elsewhere specified.

The quantity of fluorspar produced is mainly consumed in the open-hearth furnaces for the manufacture of steel and in foundry cupolas for melting pig iron; smaller quantities are used in the manufacture of opalescent glass and in the preparation of hydrofluoric acid. It is claimed that fluorspar can be used to advantage in copper and nickel smelting, particularly for the removal of silicon and arsenic during the refining of copper.

PRODUCTION OF FLUORSPAR IN THE PRINCIPAL COUNTRIES. (IN METRIC TONS.)

Year.	France.	Germany.					Spain.	United Kingdom	United States.	Total.
		Anhalt.	Bavaria.	Prussia.	Saxony.	Schwarzburg.				
1896.....	1,940	5,600	5,218	8,672	805	1,218	3	400	5,443	29,629
1897.....	2,722	7,000	4,904	10,095	592	641	2	303	4,299	34,678
1898.....	3,077	6,415	4,440	11,863	775	294	5	507	11,018	38,394
1899.....	5,140	5,815	3,631	12,932	1,355	573	310	796	21,800	52,353
1900	3,490	3,028	7,456	13,820	(a)2,019	987	4	1,472	19,646	54,862

From the official reports of the respective countries except the United States, for which the totals are based on direct returns of the producers, and for Anhalt, Saxe-Weimar and Schwarzburg-Sonderhausen, which are due to the courtesy of Herr von Scheel, director des Kaiserlichen Statistischen Amts. (a) Includes 557 metric tons from Weimar.

COMMERCIAL HYDROFLUORIC ACID.

BY KARL F. STAHL.

HYDROFLUORIC acid is made by decomposing ground fluorspar with sulphuric acid in cast-iron vessels and absorbing the resulting fumes of hydrofluoric acid in leaden vessels containing more or less water, according to the strength desired. The commercial acid, containing from 30 to 60% HF, is stored and shipped in lead vessels or gutta percha bottles. Weaker acid of about 35% and less can be stored for a limited time in wood and is sometimes shipped in whiskey barrels. The so-called "chemically pure" acid is packed, in this country, in ceresine bottles, which must be kept away from the Bunsen burner, as the melting point of the ceresine is low. In Europe the c. p. acid is shipped, either in gutta percha or platinum bottles, but in course of time the acid takes up

mineral and organic matter from the gutta percha and ceases to be c. p.—platinum bottles are the best, but require a heavy first outlay.

Impurities.—Among the unavoidable impurities always present is hydrofluosilicic acid, which is the most important because the fluorine combined with silica is perfectly useless. The source of hydrofluosilicic acid is free or combined silica in the fluorspar. American ground fluorspar containing less than 1% silica may now be purchased; samples of English spar contain about 3%, while 6 samples of German spar contained from 0·1 to 0·7% silica. The following method for the determination of silica in fluorspar is not accurate, but gives an idea of the quality: 1 g. of ground fluorspar, in a platinum dish with a small platinum spatula, is dried at about 130°C., weighed exactly, moistened with hydrofluoric acid, stirred with spatula, evaporated to dryness on the water bath; this is repeated, then dried again at 130°C. and weighed. The difference is assumed to be silica, which is only correct when free silica is present. For every part of silica in the spar about 4 parts of fluorspar and 5 parts of sulphuric acid are wasted, or for every percentage of silica at least 10% (4% for spar and about 6% for sulphuric acid) should be deducted from the value of the spar.

Sulphuric acid, which is distilled over in small quantities from the decomposing vessel, does not harm hydrofluoric acid for use in etching glass or pickling iron; but must be determined in the analysis, otherwise it would be figured as hydrofluoric acid. On evaporation and calcining, commercial acid should leave but a trace of non-volatile matter. The commercial acid of to-day usually contains from 1 to 1·5% $SiF(HF)_2$, and from 1 to 2% H_2SO_4 only as impurities, and is purified for analytical purposes by distillation in platinum vessels and by the use of c. p. sulphuric acid.

The following method is used for testing: The sample is placed in water of 15°C. for at least 5 minutes, and the sp. gr. is taken. Then with the aid of a small platinum tube, serving as a pipette, three portions are weighed out: (A) 2 g. in a 5-c.c. platinum crucible; (B) 2 g. in a 40-c.c. platinum crucible; (C) 4 g. in a small platinum dish.

A. Place the small platinum crucible, covered with its lid, in a large platinum dish, holding about 100 c.c.; then run, according to the expected percentage, 25 or 50 c.c. normal caustic solution (40 g. NaOH per liter) from a pipette into the dish, upset the covered crucible and mix the acid and alkali with a platinum stirrer, add 2 drops of a solution of phenolphthalein (1 g. in 100 c.c. alcohol) and then more of the normal soda solution from a burette till the colorless liquid assumes the characteristic bright red, which an alkali imparts to phenolphthalein. Heat to about 50°C.; the red color will disappear again; finally add normal solution from the burette slowly till the red color remains, even if heated again, which indicates that all free sulphuric acid, hydrofluoric acid and hydrofluosilicic acid has been neutralized. The number of c.c. used we call "a." If litmus is used in place of phenolphthalein, the soda solution has to be added till the color is perfectly blue, but the end of the reaction is indistinct, while with phenolphthalein it is very sharp.

B. To the acid in the large platinum crucible (2 g.) add 5 c.c. water (meas-

ured approximately), then slowly about 2 g.[1] K_2CO_3, either in small pieces or in concentrated solution; add about 15 c.c. of 50% alcohol and then about 5 c.c. 95% alcohol, which will bring the whole to a volume of about 25 c.c., containing about 50% alcohol;[2] let it stand for at least 1 hour. Filter[3] and wash the gelatinous precipitate, consisting of potassium silicofluoride, with 50% alcohol till blue litmus paper ceases to be turned red by the filtrate. Throw the filter with the precipitate into a platinum dish, add about 25 c.c. water and warm to about 50°C.; titrate slowly with normal caustic soda solution and phenolphthalein, as described in the determination of total acidity. The number of c.c. used we will call "b."

C. Place the platinum dish containing 4 g. of the acid to be tested on a water-bath under a hood and evaporate till acid fumes have completely ceased. Titrate the remaining syrupy liquid (which contains the free H_2SO_4), cold with normal soda solution, using either litmus or phenolphthalein as indicator. The number of c.c. used we will call "c."

The number of c.c. of normal soda solution used in the first titration and called "a" represent the alkali necessary to neutralize the hydrofluoric, hydrofluosilic and sulphuric acids, and to find the number of c.c. used for hydrofluoric acid alone, subtract those used for hydrofluosilicic and sulphuric acids. Having employed 4 g. of substance for the determination of the H_2SO_4, the number of c.c. used for that determination must be divided by 2. The number of c.c. used for HF alone equals $a-(\frac{3}{2}b+\frac{c}{2})$, and as each c.c. normal solution indicates 0·020 g. HF and 2 g. of substance have been used, the number of c.c. found by the above formula express the percentage of free HF, therefore $a-(\frac{3}{2}b+\frac{c}{2})$=percentage free HF. From the foregoing the calculation of the percentage of SiF_4 $(HF)_2$ is an easy matter. 1 c.c. normal NaOH indicates 0·055 $SiF_4(HF)_2$, which was obtained from 0·036 $SiF_4(HF)_2$. Having used 2 g. of substance, 0·036 must be divided by 2 and multiplied by 100 to get the percentage, or, $b\times1{\cdot}8$=percentage $SiF_4(HF)_2$. The percentage of free H_2SO_4 is obtained by multiplying (c) the number of c.c. used with 0·048, dividing by 4 and multiplying with 100, or, $c\times1{\cdot}2$=percentage free H_2SO_4. Other free acids, muriatic or nitric, which would influence the accuracy of the determination, are not likely to occur in commercial hydrofluoric acid and their presence can easily be detected by well-known analytical methods.

[1] The amount of K_2CO_3 is calculated to neutralize the acids only partly. To avoid an excess it is advisable to test the liquid with litmus paper, which should show a strong acid reaction. But there should be at least enough potash to form $SiF_4(KF)_2$ with the $SiF_4(HF)_2$. In analyzing acid of entirely unknown composition, 1·05 g. K_2CO_3 is taken for every 1 c.c. normal soda solution used for the determination of total acidity. Potassium chloride might be used in place of the carbonate, but in that case free HCl is formed, in which the silicofluoride of potassium is somewhat soluble.

[2] If the liquid contains more than 50% alcohol, fluoride of potassium is precipitated; if much less alcohol, silicofluoride of potassium may remain in solution.

[3] A platinum funnel is used, because glass funnels are acted on, but that does not influence the accuracy of the method.

FULLERS EARTH.

THE production of fullers earth in the United States during 1901 was 14,112 short tons, valued at $96,835, as compared with 11,813 short tons, valued at $70,565 in 1900, and 13,620 short tons, valued at $81,900 in 1899. The greater part of the product continues to be supplied from the mines at Quincy, Fla., the balance being obtained from the mines in Arkansas, California, Colorado, and New York.

Imports.—The imports of fullers earth in 1901 were 2,918 long tons of lump earth, valued at $17,230, and 7,851 long tons of ground earth, valued at $63,467 (total: 10,769 long tons, valued at $80,697), as compared with 2,431 long tons of lump earth, valued at $14,750 and 5,742 long tons of ground earth, valued at $50,047 (total: 8,173 long tons, valued at $64,797) in 1900. Under the present tariff the duty is $1·50 per ton on lump earth and $3 per ton on ground earth.

New York Market.—Demand for fullers earth was greatest in the spring and summer months of 1901 for use principally in filtering and clarifying oils. Large imports of English earth, chiefly powdered, sold at steady prices. The bulk of the domestic production is generally contracted for ahead, hence quotations remain practically unchanged throughout the year. Prices for ordinary lump during 1901 were 75c. per 100 lb.; refined lump, $1·25 per 100 lb., and powdered, 85c. per 100 lb.

Uses.—The chief uses of fullers earth is in fulling wool and in deodorizing and clarifying fats, oils and greases. Refiners of lard, cottolene and allied products are important consumers. Chief among these are N. K. Fairbanks Co., Swift & Co., Armour & Co., Nelson Morris & Co., Cudahy Packing Co., and G. H. Hammond & Co.

Tests of fullers earth from Bakersfield, Cal., have proven it to be equal to the English earth, and it is stated that contracts were closed with Missouri river packers and other consumers which increased the shipment for 1901 to 2,500 tons, a very considerable increase over the shipments in the previous year. The analysis of the Bakersfield fullers earth is as follows: SiO_2 54·32%, Al_2O_3 18·88%, Fe_2O_3 6·50%, CaO 1·00%, MgO 3·22%, ignition loss 11·86%, alkali (by difference) 4·21%. A comparative test of Bakersfield fullers earth with imported English fullers earth showed that 10 lb. of the former equalled in bleaching strength 9·75 lb. of the latter. The tests were made on cotton-seed oil with 5 and 10% quantities of earth at a temperature of 100°C. for 45 minutes. The English earth used analyzed: SiO_2 54·20%, Al_2O_3 14·30%, Fe_2O_3 6·30%, CaO 1·25%, MgO 2·72%, ignition loss 17·44%, alkali (by difference) 3·79%.

GARNET.

THE production of garnet for abrasive purposes in the United States during 1901 amounted to 4,444 short tons, valued at $158,100, as compared with 3,285 short tons, valued at $92,801 in 1900. The output was derived mainly from the mines in the vicinity of Ticonderoga, N. Y., which furnished 2,500 short tons, valued at $70,625 during 1901, as compared with 2,508 short tons in the preceding year. The balance of the total production in the United States was obtained from Chelsea, Pa., Roxbury, Conn., and from North Carolina. The last-named State entered the list of reporting producers in 1899, and has contributed a product of high grade. The price for garnets remained unchanged throughout the year, although the demand was slightly increased owing to the generally prosperous condition of the country and to the stocking up of a large concern which has recently entered the garnet paper trade. No new mines have been opened in the Ticonderoga region during the year.

The geology and mineralogical character of the Adirondack deposits and the preparation and uses of the mineral product are given in THE MINERAL INDUSTRY, Volume VI.

GEMS AND PRECIOUS STONES.

THE progress of the gem and precious stone industries in the United States during 1901 was mainly in the great activity displayed in the turquoise mines of New Mexico and in the emerald-beryl mines of North Carolina, owing to the increased use of the matrix as well as the gems for jewelry. The sapphire mines in Fergus County, Mont., also were actively developed by two mining companies.

DIAMONDS.—*United States.*—The diamond deposits in the United States were fully described by William H. Hobbs, THE MINERAL INDUSTRY, Vol. IX., 1900, p. 301. The production in diamonds for the year 1901, for the United States amounted to but $100 in value. The only new discovery of diamonds of interest in 1901 was the finding of a solitary gem in Lee County, Ga., the first ever found in that region.

Africa.—The report of the De Beers Consolidated Mines, Ltd., for the fiscal year ending June 30, 1901, shows that diamonds to the value of £4,628,845 were sold by the company during the year. After deducting expenditures of £2,194,207, the profit balance for the year was £2,434,639, from which dividends to the amount of £1,579,582 were paid. The average yield per load of blue ground and lumps from the De Beers and Kimberley mines for the fiscal year was 0·76 carats, at an average value per carat of 39s. 7d. The average yield per load for the Premier mine, at Wesselton, was 0·295 carats valued at 27s. 4d. each. During the year the De Beers Co. purchased the claims of Mr. Leopold Herz in the Dutoitspan mine for £12,000; this mine now belongs wholly to the De Beers Co., except for the claims owned by the Griqualand West Diamond Mining Co., which are leased to the De Beers. A new contract for the sale of the diamonds has been entered into which gives the De Beers Co. a share in the profits of sale, as well as a higher price than formerly for the diamonds. During the latter part of the year the capital stock of the company was changed from £3,950,000, divided into £5 shares, to an issue of £4,500,000 divided into 800,000 shares of preferred stock at £2 10s. par value, and 1,000,000 shares of common stock of the same par value. The preferred stock will be entitled to dividends of 40% annually. Ten thousand preferred shares are held in the treasury and the life governors accept 160,000 shares to cancel their rights which entitled them to 25% of all profits made in excess of 36% on the stock. It is reported that negotiations for the purchase by the De Beers Co. of the Jagersfontein mine were completed in 1901. American

electrical machinery to the amount of $135,000 was ordered, which included two Westinghouse-Parsons steam turbines of 1,000 kw. each, two 1,000 kw. direct-connected alternating current generators, all to be built by the Westinghouse Electric & Manufacturing Co., of Pittsburg, Pa. In the early part of the year a canary-colored diamond weighing in the rough 600 carats was found. As cut in 64 facets it weighs 207·75 carats, is absolutely flawless and has a very brilliant luster. It was exhibited at the Pan-American Exposition at Buffalo, in 1901.

The Orange Free State & Transvaal Diamond Mines, Ltd., capitalized at £550,000 in £1 shares, owns, in the Orange River Colony, approximately 12,000 acres, comprising the Kaal Vallai and Dirksburg freehold farms. The company also has leases of diamondiferous land east of Pretoria in the Transvaal. The company's machinery is capable of handling 5,000 loads of clay per day, and 250,000 tons of blue clay have been weathering on the floors during the Boer war. The Lace Diamond Mining Co., Ltd., capitalized at £250,000 in £1 shares, discovered diamonds on its property of 5,000 acres in 1898. From February to October, 1899, 47,017 loads of yellow ground were washed for a yield of 9,888·5 carats, or 21·03 carats per 100 loads. Before the war machinery capable of treating 1,000 loads per day of 12 hours was erected, and a duplicate of this plant is expected to be in operation by July, 1902. It is estimated that the company has three years of work in the yellow ground in sight before reaching the bed of blue clay known to exist in the lower levels of the property.

Australasia.—The estimated production of diamonds for the year 1901 is valued at £9,756. The diamond output for New South Wales was much restricted in 1900 owing to the extended and protracted drought. The production being but 9,828·5 carats valued at £5,663 against 25,874 carats valued at £10,349 for 1899. The mines of the Inverell Diamond Field Co., Ltd., at Copeton (formerly Boggy Camp) were closed during the greater part of the year pending a reconstruction of the company. The quantity of wash dirt treated during the year was 4,275 loads for a yield of 3,546·5 carats of diamonds, valued at £1,063. The Soldiers Hill Diamond & Tin Mining Co. recovered, from May, 1899, to December, 1900, diamonds to the weight of 5,887·5 carats valued at £4,256. The Elliot Diamond & Tin Mining Co. during 1900 treated 140 loads of wash for a yield of 637 carats of diamonds and one short ton of tin. Operations were commenced November 1, 1900. The diamonds average 3 or 4 to the carat and have been sold locally for 16s. per carat. During 1900 the Australian Diamond Fields Co., of Copeton, treated 422 loads of wash for a yield of 466 carats of diamonds valued at £350. The Malacca mine treated 70 loads of wash for a yield of 202·5 carats of diamonds valued at £160. Other small holdings of the Copeton field produced 2,400 carats of diamonds valued at £1,583. The Bingara mining division produced almost nothing during the year owing to the great scarcity of water, the nearest stream being four miles away. Diamonds are reported at Watson's creek, in the Bendemeer division and at Beryl, on the Cudgegong river, in the Mudgee mining district. At Nullagine, in West Australia, 230 tons of conglomerate were treated for a yield of 25 small diamonds valued at £24, and 77·7 oz. of gold.

South America.—The principal diamond mining States of Brazil are Bahia

and Minas Geraes. The districts of Diamantina, Jequitinhonha, Abaithe, Bagagem, and Saccado Veados, in Minas Geraes are the principal regions where mining is carried on. Diamantina is divided into the localities of Sopa, Boa Vista, Curalinho, and Lavras, the latter the richest diamond deposit in all Brazil. In the State of Bahia the most prominent districts are Sincova, Cannavieivas, and Salobro. The last-named district was supposedly exhausted in 1891, but recent investigations may lead to a revival of diamond mining there. The workings in this district were confined to the beds of the streams and shallow holes on the benches. The diamonds occurred in the naturally concentrated gravel beds, in pockets, with no regular system of occurrence. The lower diamondiferous strata was not explored owing to the limited resources of the miners and the frequent and disastrous floods. The exports of precious stones for the first seven months of 1901 from the State of Minas Geraes amounted to almost $250,000 in value.

British Guiana.—During 1901 a large number of prospectors and mining companies were operating in the Mazaruni diamond fields. The route to the fields follows the coast for 20 miles from Georgetown, thence 50 miles up the Essequibo river to Bartica, from there to San-San-Kopai Landing about 1·5 miles above Putareng creek on the left bank of the Mazaruni river. Navigation is difficult on account of the numerous rapids and cataracts, and prospecting expeditions are costly to outfit. The expense of outfitting for three months for an expedition of eight men and transporting them from Georgetown to the diamond fields is $1,000. The principal diamond diggings are five miles back from the Mazaruni river. Among the prominent companies operating in the district are: The British Guiana Diamond Syndicate; the Fogel-Armeny Syndicate, at Saranamoo; the Stripp, Menzies, and Morris Syndicate, on Jasper creek; the Marshall Syndicate; the Nascimento Syndicate; the Wieting Syndicate, between Putareng and Saranamoo creeks; the Barnard Syndicate, on Saranamoo creek; the Forbes Syndicate; the Ho-a-Hing Kenswall Syndicate; the Harrison-Richter Syndicate; and the Biallosterski Syndicate, on Putareng creek. Some of the larger syndicates have their own boats plying between the diamond fields and Georgetown. The production of diamonds for the first three months of 1902 was 3,426·5 carats, valued at $11,062 in contrast with a production for the same period of 1901 of 326 carats valued at $4,656.

Dutch East Indies.—Diamonds are found in Dutch Borneo near the sources and along the courses of the Martapoera, Riam Kiwa, Riam Kanan, and Bandjoe Irang rivers. The Bandjoe Irang field, formerly the most important, together with the region of Tjampaka, is worked out. All the fields are in the southeastern portion of Borneo, and still produce stones in small quantity but of good quality.

India.—In 1900 Central India produced 169 carats of diamonds valued at $350.

EMERALDS.—Emeralds are mined in Mitchell County, N. C., and in Blacksburg, S. C. The emeralds from Mitchell County are cut in the matrix, polished, and sold in quantities.

The Muzo and Coscuez emerald mine in Colombia is the only one in the world which is worked continuously. The mine is very crudely worked, but the emeralds are of fine color and excellent quality. The mine is located 50 miles from

Bogota, very near the route of the Inter-Continental railway. The Government of Colombia leases the mines to an English syndicate, which has made millions from its profits of operation.

The firm of Streeter & Co., of London, has a concession from the Egyptian Government to prospect for emeralds in the region of the Red Sea coast until 1904. In the winter of 1899-1900 an expedition was sent out by Streeter & Co. to explore the ancient emerald mines of Jebel Zabara, about 80 miles south of Um Rus, and 25 miles from the harbor of Sherm Sheik, on the Red Sea. In ancient times the emeralds of Zabara were noted for their fine quality and the large quantity produced. The emeralds occur in a matrix of mica schist together with large quantities of beryl. The zone of schist extends from beneath the Nubian sandstone to the westward of Jebel Nikhari, south of the Hamesh gold mines, and thence eastward to Jebel Zabara and the sea. Another zone of micaceous and talcose rock in which emeralds might be discovered lies to the north of Eridia, eastward of Keneh.

A discovery of emeralds is reported during the latter part of 1901, in the vicinity of Corocoro, Bolivia.

Emeralds are found in the Balkan Mountains, Russia, but the annual output is small and the finds are irregular.

OPAL.—Mining for opals in New South Wales is confined to White Cliffs, in the Wilcannia district, the search being limited to shallow depths. From September, 1899, there has been a steady decline in the population of White Cliffs, the estimate for August, 1899, being 2,500, while December, 1900, showed but 1,400 persons, due to the overproduction of the poorer quality of opals and the consequent restriction of mining operations. In 1900 a comparative scarcity of first-class opals was reported, buyers being unable to purchase as much as desired. During 1900 the White Cliffs Opal-Mining Co., Ltd., had 400 tributors working on the company's leases. The estimate of the value of the output of 1900 is £80,000. The declared value of the parcels weighing about 51,260 Troy oz. consigned through the postoffice was £44,417, with no estimate for amounts forwarded by coach or taken personally. The value of the production of opals for the year 1901 for the White Cliffs field is estimated at £120,000 an increase over 1900 of £40,000, which is due to the large number of men attracted to the field by the depression in the Broken Hill and Cobar mining divisions.

The principal opal mining district in Mexico is in the State of Queretaro, near La Esperanza, where large quantities are produced and cut annually of the noble opal, fire opal, harlequin, and lechosos (the latter showing red and deep-green flashes of color). The State of Hidalgo produces from Zimapan valuable quantities of the fire opal annually. At Huitzuco and San Nicolas del Oro, in the State of Guerrero the opals are transparent and streaked with red, green and blue. Opals valued at about $10,000 are said to be exported annually by one mine owner from this State. Large quantities of noble opals are mined in Central America, and opals are also mined in Arizona and New Mexico, U. S. A.

RUBY.—The report of the Burma Ruby Mines, Ltd., for the fiscal year ending February 28, 1901, shows total receipts including rubies sold, interest, etc., amounting to £110,626; the expenses amounted to £70,781, leaving a net

balance of £39,845. Deducting the percentage payable to the Government of India for rental, amounting to £12,440, there remained a net profit of £27,405, which, including the balance brought forward from the previous fiscal year, yielded a sum available for distribution of £36,286. The directors recommended a dividend of 17·5% equal to £26,162, and carried forward £10,124. During the fiscal year 947,444 loads of ruby earth were washed at an average cost of 10·29d. per load, against 888,135 loads at 10·39d. for the previous fiscal year. The erection of a two-pan washing machine at Padansho, near Kyouklongyi, was completed, enabling the output for this mine to be doubled, and the surface stripping for the opening of the new mine at Chôungzone was begun. A third electric installation for the working of this mine was received at Mogok. The Burma rubies occur in beds of coarse gravel mixed with graphite, garnet, and spinel. The Burma rubies more nearly approach the pigeon-blood color than those found elsewhere, and consequently the output is more valuable proportionately. The New Kabue Gold Mines of Siam, Ltd., although inactive in the gold field during 1900, took over the lease of the sapphire and ruby mines at Pailin. The company does not engage directly in mining but grants licenses to native diggers, and leases out the various surface rights. Bo Wen and Taphan Hin, in the Province of Chantaboon, Siam, yield the greatest output of rubies, although the Bo Yan and Navong mines, in the Province of Krat, produce large quantities annually. The Siamese rubies are much darker in color than the Burmese ones and have a tendency toward a purplish color. Occasionally the famous pigeon-blood rubies are found in the valleys and water-courses surrounding Ratnapura and Rakwena, Ceylon. While the Ceylon rubies are limpid in brilliancy and pale in color, they are not so valuable as Burmese or Siamese rubies. The total production of rubies for 1900 in India amounted to 214,856 carats. A ruby worth when cut barely £1 was found in 1900, at Beatrice creek, in the Jordan creek gold fields, Queensland, Australasia.

SAPPHIRES.—Sapphires of high quality and variegated colors and tints are found at Rock creek, in Missoula County, Mont.; on the Missouri river, between Cañon Ferry and American Bar the sapphires are bluish-green, blue, and white, and are mined in large quantities; in Deer Lodge County, on Cottonwood creek, sapphires of variegated colors are found, and at Yogo, in Fergus County, are the mines operated by the American Gem Mining Co. and the New Mines Sapphire Syndicate, of London, which last produced in 1901 about 100,000 carats of gems, and 5,000 oz. of stones, which are ground and mixed with diamond dust for use in polishing gems. The Yogo gems occur in an igneous dike, which extends for some five miles through bodies of massive gray limestone. The stones are recovered by ground-sluicing and hydraulicking; the matrix of the stones disintegrating either in the sluices or by weathering, in similar manner to the blue clay matrix of the South African diamond fields. The output of the New Mines Sapphire Syndicate is shipped to Europe for cutting, and the product of The American Gem Mining Co. is cut by lapidaries in Helena, Mont. The Yogo sapphires are equal in quality and in value to the best Ceylon and Burma product. A further account of Montana sapphires, written by W. H. Weed, will be found

later in this section. In Cowee township, Macon County, N. C., sapphires are found in seams or layers i nan altered hornblende gneiss.

At Anakie, in the Clermont district, Queensland, Australasia, sapphires to the value of £900 were mined in 1900. The stones are found under boulders in a wash not more than 3 ft. deep. The deepest workings do not exceed 14 ft. The wash is screened and sluiced and the stones recovered on tables by hand picking. The Withersfield Sapphire Co., Ltd., holds 240 acres of ground, which is expected to be actively developed in 1901. The production of sapphires for 1900 came from chance prospecting over a wide area of ground. The output of sapphires for 1900 in India amounted to 7,239 carats. In that year the New Kabue Gold Mines, Ltd., took over the lease of the sapphire mines at Pailin, Siam. The company leases the surface rights to native diggers.

TURQUOISE.—During 1901 seven mining companies were engaged in mining and marketing turquoise, mainly from the Cerrillos Mountains of New Mexico. The value of the total production from the United States during 1901 (most of which was provided by New Mexico) being $118,000. Among the mines of New Mexico are the Blue Bell, situated 2·5 miles north of Cerrillos, and the Old Castillian, owned and operated by Tiffany & Co., of New York City. Other deposits of turquoise are in the Hatchitas and Cow Spring Mountains, near Silver City, N. M. The Silver City Turquoise Co. is operating a mine 1·5 miles northeast of Burros, Grant County, N. M. It is reported that an old turquoise mine situated about 62 miles northeast of Manvel, San Bernardino County, Cal., is being operated with a small force of men by a New York company. Turquoise in some quantity and of good quality is reported from the Tonapah district of Nevada, at about 12 miles from Crow's Springs. The turquoise mines at Wady Maghara, in the peninsula of Sinai, which were again started in 1900 by the Egyptian Development Syndicate, produced a small quantity of turquoise of good quality during 1901.

TOURMALINE.—The disturbances in China caused the closing of the tourmaline mines in Mongmit, a Shan State, during all of 1901, for there is little or no demand for tourmaline outside of China. The jade mines of Myit-Kyina district, in Upper Burma were closed during the year for the same cause, although a little mining was done. The tourmaline mines of Mesa Grande, San Diego County, Cal., provided nearly all of the production of tourmaline in the United States during 1901, which amounted to a value of $15,000. A new deposit of tourmaline a short distance from the older one promises an increased output for 1902.

MONTANA SAPPHIRES.

BY WALTER HARVEY WEED.

EARLY in Montana's history, when the "bars" of the Missouri river, near Helena, the terraces and side hill deposits of river gravels were being washed for gold, the riffles in the sluice boxes sometimes held pale greenish stones which were unnoticed at first, but identified later as sapphires. The discovery awakened but little interest at a time when gold alone was the object of search. From these early days to the present the river bars have been intermittently worked by nomadic

placer miners. About 1893 the locality was visited by European gem experts, who were impressed by the brilliancy of the stones and wrote most flattering reports, which confidently predicted that despite their unconventional color, they would become popular and highly prized gems. Heavily capitalized companies, which were organized abroad, acquired large tracts of land along the Missouri, and Montana was heralded as the new Golconda. Unfortunately these expectations were not realized. The stones were abundant and of high brilliancy, but their pale greenish color did not meet with popular favor, and Montana sapphires were a drug on the market. In 1895, as a result of placering for gold, the new Yogo field was accidentally discovered, and, as the stones were of the much-prized cornflower-blue color, they met with a ready sale. The property is to-day not only the most valuable gem mine in America, but the only place where sapphires are mined in the original matrix in which they were formed, resembling in this respect the Kimberley diamond mines of South Africa.

The Missouri river localities are located 12 to 18 miles from Helena. The different bars have received names—Ruby Bar, Spokane Bar, etc., and the gravels all contain sapphires as far up stream as Emerald Bar. These gravels are from 10 to 50 ft. thick, and situated at varying elevations above the stream (130 ft. at Emerald Bar). The gems are found in situ in a dike of igneous rock 3 miles below Cañon Ferry.

As investments these bar deposits have not been remunerative because the stones are chiefly of a pale greenish yellow color, and though very brilliant, are not highly esteemed by the public. Blue and red stones of fine color are extremely rare, and the pink and yellow ones not common enough to be counted upon in washing the gravel. The Missouri river bars are therefore not now worked, and the heavily capitalized corporations formed to mine the gems are financial failures.

The Rock creek locality is about 30 miles west of Anaconda and the same distance southwest of Phillipsburg, in Granite County. The sapphires occur in the gravels of several small streams forming the central headwaters of Rock creek. These placer claims have been extensively worked in the past three years, yielding several hundred thousand carats of rough stones, of which about 6% are fit for cutting. The gems occur only in stream gravels, but a few specimens are found in the original matrix of igneous rock. The gems from this locality, though greenish or blue-green, are deeper colored than those from the Missouri Bars, and meet with a ready sale in Montana, where they bring prices but little less than those of the blue stones.

The Cottonwood creek locality is about 10 miles east of Deerlodge, on the headwaters of the stream that flows through the town. The gems occur only in stream gravels, are of the usual pale greenish color, and the deposits have as yet been but little worked.

The Yogo mines, situated in the eastern footslopes of the Little Belt Mountains, are near the junction of Yogo creek with the Judith river, 15 miles from Utica, which is the nearest town, and accessible by stage from the terminus of the Montana railroad or from Great Falls. The gems occur in a dike of dark gray igneous rock, forming the sapphire vein, which has been traced for a distance of nearly five miles from the meadows of the Judith river across barren limestone hills

to the cañon walls of Yogo gulch and beyond. This remarkable dike, for the vein is a true dike of igneous rock, cuts white limestones (Carboniferous) and the red clays and dark shales which overlie them to the east. The gems occur in corroded forms and in well-defined crystals somewhat sparsely distributed throughout the rock. The dike rock is, when unaltered, of a very dark gray color and dotted with white and pale green inclusions. It consists of brown mica (biotite) and green pyroxene (diopside) and is classed as a basic *minette*. The inclusions consist of fragments of limestone or shale altered to calcite diopside and quartz.

The present workings consist of great open cuts, one of them 700 ft. long and 90 ft. deep, another 1,200 ft. long and 20 to 50 ft. deep, besides tunnel and shaft workings. Much of this open cut work has been done by hydraulic mining wherever the slope of the hillside permitted one end of the cut to reach the surface. The upper part of the vein consisted of a coarse breccia composed of fragments of altered limestone and shale in a yellow clay. These fragments diminish in amount in depth, and the mass of the dike is a yellowish brown clay, but this changes at 20 to 50 ft. in depth to a blue clay in which there are boulders and masses of the still fresh and undecomposed igneous rock. This blue clay, like that of the Kimberley diamond fields, is a product of the alteration of the igneous rock. It is a very important factor in the economical working of the mines, as it would be all but impossible to extract the gems from the original rock itself, whereas the blue clay disintegrates readily on weathering.

Ths material is worked by washing it into sluice-boxes similar to those used in ordinary placer mining for gold. The boxes are set with less fall than for gold and the riffles made slightly higher, as the sapphires are not so heavy as the gold, and hence would wash away. The "dirt" mined in the open cuts is screened and the fine material carted to the sluice-way to be washed, while the lumps are gathered in heaps to slowly disintegrate through weathering. This process is hastened by occasional wetting, which, with the freezing incident to the usual and almost nightly frosts of this altitude, aid the process. This disintegrated material is subsequently washed in the sluice-boxes. The material caught in the riffles is "cleaned up" and treated in an ordinary gold rocker fitted with three screens of different mesh. This eliminates much of the waste, and the resulting concentrate is panned by hand. The residual material consists of small irregular lumps of pyrite and the sapphires, and from this the gems are picked by hand. Formerly the small chips were rejected, but there is now a market for all the material, not only the larger gems, but also for the smaller ones for watch jewels. The stones are mostly small, a large proportion being flat discs showing the triangle (the so-called signature of the sapphire) in relief. Gems of 4 to 5 carats are rare. The largest stones found weighed from 11 to 12 carats and cut to gems of 5 to 6 carats. These larger stones are valued at $75 a carat, but the smaller ones sell at retail at $30 to $40 per carat, according to the stone. In 1901 the output was about 150,000 carat of cuttable material.

Origin of Sapphires.—From the foregoing brief description it will be seen that the gems occur in dikes of igneous rock, both at Yogo and near Helena. The dike rock is different in the two localities, being a basic minette composed of only pyroxene and biotite at Yogo and an altered augite-mica-syenite in the Mis-

souri river locality. These are both very basic rocks, thus emphasizing the resemblance to the occurrence of diamonds in Africa. Sapphires have been formed artificially from alumina dissolved in molten glass, from which crystals separated out in cooling.[1] There is therefore no reason to doubt that the Montana gems originate from fragments of shale gathered from the walls of the fissure and carried upward as the liquid igneous magma filled the crack. These fragments dissolved in the liquid rock which then became extremely rich in alumina, which element, upon cooling, crystallized out as sapphires. It also seems certain that corundum is sometimes an original constituent of igneous rock.

[1] Morozewicz, *Zeitschrift fuer Krystallographie*, Vol. XXIV., 1895, p. 281.

GLASS.

THE remarkable growth of the glass industry is shown by a comparison of the figures obtained from the Census Bulletin of 1900 for the decades 1890-1900 and 1880-1890, summarized respectively as follows: Number of establishments 355, against 294; capital $61,423,903, against $40,966,850; salaried officials, clerks, etc., number, 2,268, against 1,095; salaries $2,792,376, against $1,232,561; wage earners, average number, 52,818, against 44,892; total wages $27,084,710, against $20,885,961; miscellaneous expenses $3,588,641, against $2,267,696; cost of material used $16,731,009, against $12,140,985; value of products $56,539,712, against $41,051,004. The total cost of fuel in 1900 was reported as $3,203,146, of which amount natural gas cost $1,575,278, coal $1,074,074, and oil $409,158, the remainder being divided between coke and wood. Some Indiana establishments reported little or no cost for fuel, gas being supplied to them as an inducement for location, or because they owned their own gas wells. The cost of packages and materials for same was $3,390,627 in 1900, against $1,853,462 in 1890, an increase of 82·9%, due to the general demand for a safer and neater package and the increased use of the carton package for lamp-chimneys, etc. Soda ash was used in 1900 to the amount of 157,779 tons at a cost of $2,259,939, against 96,777 tons, costing $3,108,233 in 1890, the average cost per ton being $14·32 and $32·12, respectively, the decrease being due to the development in America of the soda ash industry.

The increase in the value of glass products between 1890 and 1900 was 37·7%, but probably the increase in quantity was in excess of this figure, especially in the output of bottles, jars, and glassware owing to the general introduction of the tank melting furnace and the adoption of improved mechanical equipment. The number of pieces of glassware, bottles, jars, etc., manufactured was not reported at the census of 1890, hence the impossibility of any comparison with the 1900 census. The total production of plate glass, rough and polished, in 1890 was 12,206,942 sq. ft., against 17,512,262 sq. ft. in 1900, an increase of 43·5%. The production of cathedral glass in 1890 was 2,773,824 sq. ft., against 8,846,361 sq. ft. in 1900, an increase of 218·9%. The outputs of skylight and wire glass in 1900 were 3,679,694 and 1,295,504 sq. ft., respectively, with no report for 1890. The production of window glass in boxes in 1890 was 3,768,884, against 4,341,282 in 1900, an increase of but 15·2%, which is accounted for by the shorter "run" during the "fire," the average "run" being about 6 months in

1900, against nearly 10 months in 1890; besides, labor was very scarce during 1900.

In addition to the 355 active establishments in 1900, there were 60 establishments idle during the census year, no account being taken of the permanently deserted and abandoned factories. Of the 60 idle factories, 41 with a capital of $2,296,587 manufactured pressed and blown ware, or bottles and jars. The remaining 19 idle works were building glass manufactories with a capital of $1,247,949.

New Establishments.—The following companies were incorporated or announced to be incorporated during 1901: In April, 1901, the Mississippi Glass Co. was organized in New Jersey with a capital of $1,500,000 to control the output of wired glass in the United States, and consolidated the following companies: the Mississippi Glass Co., the Besto Glass Co., the Wire Glass Co., of Pennsylvania; the American Wire Glass Manufacturing Co., and the Appert Glass Co. The glass is being produced at the works of the Mississippi Glass Co. at St. Louis, and the Appert Glass Co. at Port Allegheny, Pa. Announcement was made of a recent order of 100,000 ft. for the Japanese Government, and that the use of wire glass for fireproof shutters of large buildings was increasing. Prices announced were 15c. per sq. ft. for 0·25 in. glass in stock sheets. The Columbia Plate Glass Co.'s new $1,000,000-plant at Blairsville, Pa., with an annual capacity of 1,500,000 ft. of glass, is expected to be in operation by June 1, 1902. Early in 1902 the new window glass plant at Danville, Ill., was started. The plant employs about 150 men, and is the largest in the State. It is expected that a large glass plant will be established about the middle of 1902 at Stockton, Cal., at a cost for plant of $60,000. An Eastern concern will move its plant to this place with its 150 employees to take advantage of an exceptionally fine deposit of manganese ore (used for tinting glass) near Tesla, close to Stockton. The Atlas Glass & Metal Co., capitalized at $1,000,000, was organized in West Virginia during the latter part of 1901 to operate factories at Wheeling and Clarksburg, W. Va., and Washington, Pa. The Yonkers Glass Co., capitalized at $100,000, was organized early in 1902 in New Jersey. The Ohio Glass Co., with a capital of $50,000, was organized to operate a factory for the manufacture of prescription bottles, at Sisterville, O.; the factory will cost $30,000, and it is expected to be in operation early in 1902. The Diamond Cut Glass Co. was organized early in 1901 to manufacture cut glass in Jersey City, N. J.; the capitalization is $50,000. The Kokomo Glass Manufacturing Co., capitalized at $35,000, was organized late in 1901 to manufacture glassware at Kokomo, Ind. During the latter part of 1901 the New Martinsville Glass Co., at New Martinsville, W. Va., increased its capital stock from $50,000 to $100,000.

Tariff Decisions.—In a circular dated May 7, 1901, the Treasury Department announced that the custom of assessment which prevailed for some 80 years previously would be altered from assessing on plate and window glass by superficial area in square inches, to arbitrarily bracketing the sizes by length and breadth measurement of the piece without regard to the number of square inches contained therein, also that the ruling would apply on all glass imported after September, 1900, thus compelling the jobbers to pay the excess duty on glass sold under

the old ruling for nearly a year. The duty had been paid under protest by importers at St. Louis and Boston, but New York, Philadelphia, Chicago, Cincinnati and Louisville escaped until the lack of uniformity brought to the attention of the department, resulted in the circular of May 7, 1901. The effect of this decision is virtually to exclude the long narrow strips of glass which were formerly sold by foreign manufacturers at less than cost prices, and is a corresponding benefit to American manufacturers.

Review of Prices.—The Independent Glass Co., which had a working agreement with the American Window Glass Co., during 1900, was incorporated early in 1901. A new list was issued under date of January 21, 1901, by the National Window Glass Jobbers' Association, which announced the following discounts to the trade: less than car lots, 88%; car lots, 90% from list. These prices were universal for single and double strength glass. In March prices were advanced to 85% and 5% for less than carloads, and 87·5% in carloads. In April discounts were 85% for less than car lots, and 85% and 10% and 2·5% for carloads. In May, and from thence on to November 1, the prices were 80% and 20% discount for less than carloads, and 85% and 5% for carloads. When the furnaces went out of blast at the customary time early in May the outlook was most favorable, the market was strong and the stock on hand was a little less than normal. In November the competition of outside factories and imported glass resulted in a ruling of the Jobbers' Association, permitting jobbers generally to establish their own prices, and later in the month the prices were made 90% discount for less than car lots from store; 90% and 7·5% discounts for carloads from store, and 90% and 12·5% discount for carloads f. o. b. factory. Later in the year these prices were shaded materially in the attempt to force outside glass factories into a price agreement with the result that the year closed with a demoralized market.

Germany.—Two important glass works of Germany are situated in the district of Brunswick, both of which export important quantities of optical and plate glass to the United States annually. The Deutsche Spiegelglas Actien Gesellschaft, at Freden, Province of Hanover, manufactures plate glass and lenses for eyeglasses. The incorporated firm of Voigtlaender & Sohn Actien Gesellschaft manufactures optical glass and scientific instruments. Recently the firm established a branch factory in the city of New York, U. S. A. During 1900 the value of the optical and plate glass shipped from the district of Brunswick to the United States amounted to $82,193, the value of the scientific instruments being $1,379. The factory of Voigtlaender & Sohn was established in the city of Brunswick in 1756. It employs 260 hands and has a staff of 15 foremen who have had technical education. Among the articles manufactured are photographic objectives of all sizes and systems; euryscopes; astigmatic collinears, and apochromat-collinears, used by photographers and for process work of all kinds. Recently in the construction of its instruments the firm introduced a new alloy of aluminum and magnesium called magnalium, which greatly reduces their weight and renders them weatherproof. The short rifle telescope, in general use by sportsmen in Germany, is one of the specialties of this firm.

The glass factories of Lorraine, numbering four, make glassware of all kinds

and prices—watch glass, spectacle glass, lamp glass, window glass, glass for pendules and for scientific instruments, etc. Most of the output is exported to the United States and other countries. The increase in the export trade in glass from Lorraine is shown by the following figures: $67,177 for 1898, $139,498 for 1899, and $177,576 for 1900.

Roumania.—Four glass manufacturing works supply Roumania with about all the cheap glassware it can consume. The works established at Azuga, with office at Bucharest, is owned by a limited corporation, and produces from $77,200 to $96,500 of glassware annually, working three shifts of laborers per 24 hours. Their products are colored, ordinary and cut, hollow glassware and engine-turned glass articles. The factory at Bogdanesci, in the district of Bascau, is owned by the Weisengrun firm of Jassy, employs from 80 to 100 workers, and manufactures annually ordinary hollow glassware valued at about $38,600. The rather primitive glass works at Storesci, in the district of Botosani, produce hollow glassware of the common type, cylinders for lamps, medicine and ink bottles, etc., the annual output amounting to from $19,300 to $28,950. The factory at Heci-Lespezi, in the district of Suceava, has two Siemen's gas-ovens, employs 200 hands, and manufactures, besides ordinary hollow glassware, fine, cut, white and colored goods, largely sold in Roumania, but to some extent in Bulgaria and Turkey. The factory for the manufacture of glass plates at Ciobanesci, in the district of Bascau, was established early in 1900 and has a capital of $77,200. The importation of cheap or ordinary glassware into Roumania amounts to practically nothing, but there is a small market for the better quality of articles.

Technology.—A process for producing glass vessels of an unusually large size was invented during 1901 by Paul Sievert, of Dresden, Germany, which consists in pouring the liquid glass on a cast-iron plate, where it hardens as soon as it reaches the projecting edges. The still refractory glass frees itself from the plate (the hardened edge remaining fast) and forms an elongated sack, the bottom of which rests upon a table. Compressed air is conveyed to the sack by means of a hollow cylinder and a plate pierced with holes, and the sack is blown to the required size while the table is being lowered. While the table continues to sink, the upper glass edge is freed by the removal of the projecting edge of the plate and the finished vessel is allowed to cool. Formerly concave glass vessels above 26·4 gal. capacity could not be blown, but it is stated that bath tubs and large kettles may be blown by the new method. An electrical method reported to be in use in Cologne, Germany, is described as follows: The components of the glass after mixing are exposed on a series of platforms arranged in steps, to the action of the voltaic arc. The fusion is gradually increased on the succeeding steps, and at the foot of the staircase furnace the material falls into a receiver which communicates with a second receiver at the bottom, where it is cleansed of its impurities, and finally reaches a third receiver from which it is taken to be worked.

A proposed method of M. Leon Lemal for coloring glass by penetration is described as follows: A little silver salt is sprinkled on the surface of the glass, which is then heated to 500° or 550°C. When the excess of salt has been removed the surface of the glass appears yellow, the color penetrating to a depth of

0·17 mm. after 5 minutes of baking. In an hour double that depth would be colored; after 18 hours the glass would be penetrated through 1·6 mm. of depth. To transfer a lace pattern on glass, the lace should be dipped in a 0·001 solution of silver nitrate and then into potassium sulphide. It is reported that colored monograms may be obtained in this way, and that ordinary collodion negatives can be printed on glass in various colors by this method; silver and copper give a red, and gold and iron salts have also been used. When the baking is continued for a long time the coloring matter should be renewed every six hours.

United States Patents Nos. 688,923 and 688,924, of December 17, 1901, issued to G. W. Blair and H. J. Hays, cover a window glass blowing machine, which is expected to be in use during 1902. According to the specifications, the cylinders are formed over a circular mold centrally projected through the surface of the molten glass in the furnace, by the insertion of a properly shaped dome-like metallic gathering head of circular form over and around the orifice and into the fluid glass surrounding it, which adheres to it as it would to a blowpipe. The cap or gathering head is then withdrawn slowly, the glass adhering to it forming the beginning of a hollow glass cylinder, which is increased in size by air interiorly supplied through the projecting orifice of the gathering head. This projecting orifice prevents the cylinder from collapsing while it is being drawn upward through the furnace-crown, or suitable glass-holding receptacle. The machine in question has been under construction in Allegheny, Pa., during the past three years.

A machine for blowing glass bottles, etc., has been perfected by M. Claude Boucher, of Cognac, France, by which one workman with two assistants is able to turn out 600 bottles weighing from 600 to 700 g. each, in from 10 to 11 hours, the blowing being done by compressed air. For a detailed account of this invention reference should be had to the *Bulletin de la Société d'Encouragement*, May 30, 1901.

GOLD AND SILVER.

THE production of gold in the world during 1901 was 12,812,792 fine oz., valued at $264,840,477, as compared with 12,614,633 fine oz., valued at $260,743,830 in 1900. This slight increase was due chiefly to the United States, Mexico, Russia, Rhodesia and Australia.

The United States continues to occupy the foremost position as a gold-producing country, with Australia second, Russia third, and Canada fourth. These four countries produced in the aggregate nearly 80% of the total world's production of gold in 1901. The largest individual increase in gold output was in Russia amounting to 181,152 oz., valued at $5,744,543, while the Transvaal, which was the chief producer in 1898, contributes an output even less than in 1900, the total production for this country in 1901 being but 238,991 fine oz., valued at $4,939,944. Deducting the Transvaal output from the grand totals for 1900 and 1901, the statistics show an increase in the other gold-producing countries of $10,171,000 for 1900, and $6,366,572 for 1901.

PRODUCTION OF GOLD IN THE UNITED STATES.

State or Territory.	1898.		1899.		1900.		1901.	
	Fine Ounces.	Value. (a)	Fine Ounces.	Value. (a)	Fine Ounces.	Value. (a)	Fine Ounces.	Value. (a)
Alaska	136,430	$2,820,000	247,944	$5,125,000	364,385	$7,531,835	334,000	$6,904,000
Arizona	116,110	2,400,000	124,577	2,575,000	131,834	2,725,000	202,856	4,193,400
California	740,208	15,300,000	780,527	15,100,000	757,136	15,650,000	760,973	15,730,700
Colorado	1,188,584	23,534,531	1,282,471	26,508,675	1,391,486	28,762,086	1,402,875	29,000,000
Idaho	99,178	2,050,000	84,664	1,750,000	100,000	2,067,000	110,000	2,273,900
Montana	253,890	5,247,913	233,147	4,819,157	249,153	5,150,000	243,000	5,023,300
Nevada	145,138	3,000,000	107,644	2,225,000	97,910	2,023,803	145,125	3,000,000
New Mexico	23,222	480,000	24,190	500,000	36,284	750,000	40,292	832,900
Oregon	58,862	1,216,669	62,893	1,300,000	79,342	1,640,000	86,000	1,777,800
South Dakota	276,790	5,720,000	282,944	5,848,464	320,513	6,625,000	319,361	6,601,800
Southern States (b)	12,731	263,153	8,466	175,000	11,127	230,000	16,584	342,900
Utah	114,777	2,372,442	166,909	3,450,000	200,296	4,140,000	185,000	3,824,300
Washington	29,028	600,000	32,656	675,000	38,703	800,000	30,000	620,200
Other States	3,760	77,722	2,164	44,725	3,145	65,000	4,512	93,200
Total domestic	3,148,642	$65,082,480	3,391,196	$70,096,021	3,781,310	$78,159,674	3,880,578	$80,218,800
Foreign	1,065,552	22,024,960	1,423,449	29,422,691	1,948,519	40,275,888	1,730,856	35,776,794
Grand total	4,214,194	87,107,390	4,814,645	99,518,712	5,729,829	118,435,562	5,611,434	115,995,674
Total domestic—kg	97,933	.....	105,471	.....	117,611	.....	120,698	.....
Total foreign—kg	33,142	.....	44,274	.....	60,605	.....	53,835	.....
Grand total—kg	131,075	.....	149,745	.....	178,216	.....	174,533	.....

(a) 1 oz. gold = $20·67; 1 kg. = $664·60. (b) Virginia, South Carolina, North Carolina, Georgia, Alabama and Texas. (c) Estimate furnished by Mr. G. E. Roberts.

GOLD PRODUCTION OF THE WORLD.

Countries.	1899.			1900.			1901.		
	Fine Ounces.	Kilograms.	Value.	Fine Ounces.	Kilograms.	Value.	Fine Ounces.	Kilograms.	Value.
AMERICA, NORTH:									
United States	3,391,196	105,471·0	$70,096,021	3,781,310	117,604·6	$78,159,677	3,880,578	h120,691·0	$80,218,800
Canada	1,018,371	31,674·6	21,049,780	1,350,176	41,992·4	27,908,153	1,183,465	36,807·4	24,462,222
Newfoundland	2,600	80·9	53,742	2,400	74·6	49,608	2,110	65·6	43,613
Mexico (*a*)	448,832	13,960·1	9,277,351	455,204	14,158·3	9,409,063	499,725	15,554·2	10,329,316
Central America	25,402	790·0	525,084	38,703	1,203·7	800,000	49,831	1,549·8	*e* 1,030,000
AMERICA, SOUTH:									
Argentina	3,628	112·8	*e* 75,000	2,112	65·7	43,655	2,112	65·7	43,655
Bolivia	7,256	225·6	*e* 125,000	7,256	225·6	*e* 150,000	8,466	263·3	*e* 175,000
Brazil	107,644	3,348·1	2,225,000	127,820	3,975·4	2,642,060	145,138	4,514·0	*e* 3,000,000
Chile (*b*)	46,110	1,434·1	*e* 953,100	43,541	1,354·2	*e* 900,000	21,771	677·1	*e* 450,000
Colombia	111,272	3,462·2	2,300,000	111,272	3,460·7	*e* 2,300,000	100,145	3,114·7	*e* 2,070,000
Ecuador	6,047	188·1	125,000	9,676	300·9	200,000	12,700	394·9	*e* 262,500
Guiana (British)	108,269	3,367·5	2,238,040	110,640	3,441·0	2,286,918	92,032	2,862·3	1,902,301
Guiana (Dutch)	26,972	838·9	557,532	27,082	842·3	559,793	28,938	*e* 900·0	598,140
Guiana (French)	80,072	2,490·5	1,655,088	68,353	2,126·0	1,412,857	58,055	1,805·6	*e* 1,200,000
Peru	41,636	1,295·0	860,616	58,357	1,815·0	1,206,249	80,369	2,499·6	1,661,234
Uruguay	1,961	61·0	40,540	2,288	71·0	47,187	2,411	*e* 75·0	49,845
Venezuela	49,191	1,530·0	1,016,838	49,194	1,530·0	1,016,838	49,194	*e* 1,550·0	1,016,838
EUROPE:									
Austria	2,434	75·7	50,310	2,279	70·9	47,120	2,279	*e* 70·9	47,120
Hungary	98,677	3,069·0	2,039,657	105,143	3,270·1	2,173,308	105,143	*e* 3,270·1	2,173,308
France	8,681	270·0	179,442	6,527	203·0	134,914	6,527	*e* 203·0	134,914
Germany (*d*)	3,601	112·0	74,485	3,601	112·0	74,485	3,601	*e* 112·0	74,485
Italy	3,643	113·3	75,301	1,849	57·5	38,215	1,849	*e* 57·5	38,215
Norway	74	2·3	1,539	86,813	2,700·0	1,794,420	86,812	*e* 2,700·0	1,794,420
Portugal	7	0·2	150	84	2·6	1,728	84	*e* 2·6	1,728
Russia	1,159,214	36,056·3	23,963,016	1,072,434	33,354·2	22,167,201	1,253,592	38,988·5	25,911,744
Spain	387	12·4	8,000	377	11·7	7,800	370	*e* 11·2	7,648
Sweden	3,414	106·2	70,580	3,414	106·2	70,580	2,845	88·5	58,817
Turkey	375	*e* 11·6	7,751	375	11·6	7,751	643	*e* 20·0	13,292
United Kingdom	2,845	88·5	58,810	12,760	396·8	263,749	9,664	300·6	199,754
AFRICA:									
Transvaal	3,529,826	109,782·6	72,961,501	348,760	10,846·9	7,208,869	238,991	7,432·9	4,939,944
Abyssinia	20,196	*e* 628·0	416,000	33,865	1,053·3	700,000	33,865	1,053·3	*e* 700,000
Rhodesia	54,241	1,687·0	1,127,170	79,354	2,468·0	1,640,251	148,753	4,626·4	3,074,730
Soudan	2,701	*e* 84·0	55,830	2,701	84·0	55,826	2,701	*e* 84·0	55,826
West Coast	33,978	1,005·7	702,327	36,284	1,128·5	*e* 750,000	30,000	933·0	620,100
Madagascar	11,060	*e* 344·0	228,622	33,471	1,041·0	691,849	36,244	1,128·5	*e* 750,000
Mozambique	5,416	*e* 168·4	111,918	8,475	263·6	*e* 175,176	12,377	384·9	255,840
ASIA:									
Borneo (British)	11,168	347·3	230,850	19,873	616·9	410,038	21,771	677·1	*e* 450,000
China	273,240	8,501·4	5,650,000	208,031	6,470·1	4,300,000	145,138	4,514·0	3,000,000
East Indies (Dutch)	7,234	225·0	149,527	26,609	827·5	550,000	43,541	1,354·2	*e* 900,000
India (British)	457,021	14,214·0	9,446,624	512,710	15,946·0	10,597,712	455,870	14,178·2	9,422,855
Japan	53,998	1,679·4	1,116,129	68,485	2,130·0	1,415,598	73,952	*e* 2,300·0	1,528,580
Korea	70,954	2,205·9	1,466,690	87,882	2,733·3	1,816,525	111,272	3,460·7	*e* 2,300,000
Malay Peninsula	16,459	512·0	340,200	17,048	530·2	352,382	*e* 18,000	559·8	372,060
AUSTRALASIA (*f*)	3,810,180	118,500·0	78,755,372	3,568,279	110,978·5	73,756,325	3,728,057	115,947·8	77,058,938
Unspecified (*g*)	21,771	677·1	*e* 450,000	21,771	677·1	450,000	21,771	677·1	450,000
Totals	15,139,140	470,808·7	$312,911,383	12,614,633	392,331·8	260,743,889	12,812,792	398,507·0	264,840,477

(*a*) Figures based on exports of ores, matte, etc., and coinage. (*b*) Computed from exports. (*c*) As reported by the *Statistique de l'Industrie Minerale*. (*d*) Production from domestic ores. (*e*) Estimated. (*f*) Includes six States and New Zealand. (*g*) Includes Servia, Persia, West Indies, Formosa, British New Guinea and Philippine Islands. (*h*) Estimate furnished by Mr. George E. Roberts, Director of the United States Mint.

NOTE.—The value of gold is $20·67 per ounce, which is equivalent to $664·60 per kilogram.

The production of silver in the world during 1901 amounted to 174,851,391 Troy oz., valued at $102,769,792, as compared with 180,093,364 Troy oz., valued at $110,451,012 in 1900, showing a decrease in production of 5,241,973 oz. The United States continued to occupy the foremost position as a silver-producing country, followed by Mexico, these two countries producing collectively 60% of the total output of silver in the world during 1901. The production of silver in Germany is derived largely from imported ores and bullion, and consequently

should be credited to other countries as has been done in the subjoined tables.

PRODUCTION OF SILVER IN THE UNITED STATES.

State or Territory.	1898.		1899.		1900.		1901. (c)	
	Troy Ounces.	Commercial Value. (a)	Troy Ounces.	Commercial Value. (a)	Troy Ounces.	Commercial Value. (a)	Troy Ounces. (b)	Commercial Value.
Alaska.....	150,000	$87,390	150,000	$89,370	200 000	$122,660	55,000	$32,423
Arizona.....	2,250,000	1,310,850	2,000,000	1,191,600	1,750.000	1,073,275	2,995,000	1.765,553
California....	650.000	378,690	600,000	357,480	1,170,902	718,114	1,118,333	649,257
Colorado.....	23,502,601	13,692,615	23,114,688	13,771,731	20,336,712	12,472,500	20,833,333	12,281,250
Idaho.....	6,284.744	3.661,492	4,800,000	2,859,840	6,100,000	3,741,180	4,000,000	2.358.000
Montana	14,818,662	8,633,352	16,850,755	10,039,690	17,300,000	10,610,090	14,000,000	8.253.000
Nevada.....	800,000	466,080	575,000	342,585	1,300,000	797,290	4,000,000	2,358.000
New Mexico.	450,000	262,170	550,000	327,690	550,000	337,315	434,300	256,020
Oregon	128,326	74,763	140.000	83,412	150,000	91,995	125,000	73,686
South Dakota	325,600	189,345	350,000	208.530	210.000	128,793	364,180	214,655
Texas.....	500.000	291,300	450.000	268,110	525,000	321,983	477,400	281,427
Utah.....	6,570,256	3,827,773	7,183,107	4,279,695	9,569,188	5,868,780	10,250,000	6,042,375
Washington..	275,000	160,215	300,000	178,740	300.000	183,990	350,000	206,325
Others.....	50,443	29.388	63 284	37,705	100,000	61,330	150,792	88,892
Totals ...	56,755,032	$33,065,482	57,126,834	$34,036,168	59,561,797	$36,529,250	59,653,788	$34.860,863

(a) The average value in 1898 was 58·26c.; in 1899, 59·58c.; in 1900, 61·33c., and in 1901, 58·95c. (b) Estimate furnished by Mr. George E. Roberts, Director of the United States Mint.

SILVER PRODUCTION OF THE WORLD.

Countries.	1900.			1901.		
	Troy Ounces.	Kilograms.	Commercial Value.	Troy Ounces.	Kilograms.	Commercial Value.
AMERICA, NORTH:						
United States.....	59,561,797	1,852,564·4	$36,529,250	59,653,788	f 1,855,425·6	$34,860,863
Canada	4,468,225	138,976·2	2,740,362	5,078,318	157,952·1	2.993,668
Mexico (a).....	55,804,420	1,735,697·7	34,224,851	55,152,340	1,715.416·0	32,512,304
Central America.....	1,446,705	45,000·0	887,319	1,072,095	33,345·6	632,000
AMERICA, SOUTH:						
Argentina.....	383,561	11,930·0	235,238	383,561	e 11,930·0	226,109
Bolivia.....	10,432,695	324,490·4	6,398,366	9,329,941	e 290,191·3	5,500,000
Chile (b).....	5,772,791	179,552·4	3,540,453	5,772,789	e 179.552·4	3,403,059
Colombia.....	2,800,000	87,089·0	1,717,240	2,520,000	78,380·1	1,485,540
Ecuador.....	81,000	251·9	49,677	84,818	2,638·1	50,000
Peru (a).....	6,590,955	205,000·0	4,042,433	6,655,257	e 207,000·0	3,923,274
EUROPE:						
Austria.....	1,272,279	39,572·0	780.289	1,272,279	39,572·0	750.008
Hungary.....	649,511	20,201·9	398,345	649,511	20,201·9	382.887
France.....	452,268	14,067·0	277,376	452,268	e 14,067·0	266.612
Germany (c).....	5,412,589	168,349·0	3,319,028	5,412,589	e 168,349·0	3,190,721
Greece.....	1,011,856	31,472·0	620,571	1,011,856	e 31,472·0	596.489
Italy.....	1,002,115	31,169·0	614,597	1,002,115	e 31,169·0	590,746
Norway.....	147,895	4,600·3	90,704	147,895	e 4,600·0	87,184
Russia.....	112,175	3,489·0	68,797	112,775	e 3,489·0	66,127
Servia.....	18,386	570·0	11,276	18,326	e 570·0	10.803
Spain.....	5,909,418	183,802·0	3,624,246	5,909,418	183.802·0	3,483,602
Sweden.....	61,955	1,927·0	37,997	61,955	e 1,927·0	36.522
Turkey.....	420,286	13,352·0	263,283	65,363	e 2,033·0	38,531
United Kingdom.....	190,850	50,936·0	117,048	167,000	e 5,194·2	98,447
ASIA:						
Dutch East Indies.....	73,690	2,292·0	45,194	73,690	e 2.292·0	43,440
Japan.....	1,895,398	58,958·0	1,162,448	1,895,398	e 58,958·0	1,117,337
Australasia.....	14,063,244	437,412·3	8,624,088	10,848,420	337,420·9	6,395.144
Other countries (d).....	48,226	1,500·0	29.577	48,226	1,500·0	28,429
Totals.....	180,093,364	5,599,216·2	$110,451.012	174,851,391	5,438,443·2	$102,769,702

(a) Statistics compiled from exports and coinage. (b) Exports of silver in all forms. (c) Silver produced from domestic ores only. (d) The output is mostly from China and Persia. (e) Estimated. (f) Estimate furnished by Mr. George A. Roberts, Director of the United States Mint.

NOTE.—Unless specified to the contrary, the statistics have been taken from official sources or have been collected directly from the producers by THE MINERAL INDUSTRY. The average commercial value of silver for 1900 was 61·33c. per ounce, which is equivalent to $19·718 per kilogram. The value for 1901 was 58·95c. per ounce, equivalent to $18·958 per kilogram.

GOLD PRODUCTION OF THE WORLD.

Countries.	1899.			1900.			1901.		
	Fine Ounces.	Kilo-grams.	Value.	Fine Ounces.	Kilo-grams.	Value.	Fine Ounces.	Kilo-grams.	Value.
AMERICA, NORTH:									
United States	3,391,196	105,471·0	$70,096,021	3,781,310	117,604·6	$78,159,677	3,880,578	h120,691·0	$80,218,800
Canada	1,018,371	31,674·6	21,049,730	1,350,176	41,992·4	27,908,153	1,188,465	36,807·4	24,462,222
Newfoundland	2,600	80·9	53,742	2,400	74·6	49,608	2,110	65·6	43,613
Mexico (a)	448,832	13,960·1	9,277,351	455,204	14,156·3	9,409,063	499,725	15,554·2	10,329,316
Central America	25,402	790·0	525,034	38,738	1,208·7	800,000	49,831	1,549·8	e 1,030,000
AMERICA, SOUTH:									
Argentina	3,628	112·8	e 75,000	2,112	65·7	43,655	2,112	65·7	43,655
Bolivia	7,256	225·6	e 125,000	7,256	225·6	e 150,000	8,466	263·3	e 175,000
Brazil	107,644	3,348·1	2,225,000	127,820	3,975·4	2,642,060	145,138	4,514·0	e 3,000,000
Chile (b)	46,110	1,434·1	e 953,100	43,541	1,354·2	e 900,000	21,771	677·1	e 450,000
Colombia	111,272	3,462·2	2,300,000	111,272	3,460·7	e 2,300,000	100,145	3,114·7	e 2,070,000
Ecuador	6,047	188·1	125,000	9,676	300·9	200,000	12,700	394·9	e 262,500
Guiana (British)	108,269	3,367·5	2,238,040	110,640	3,441·0	2,286,918	92,032	2,862·3	1,902,301
Guiana (Dutch)	26,972	838·9	557,532	27,092	842·3	559,793	28,938	e 900·0	598,140
Guiana (French)	80,072	2,490·5	1,655,088	68,353	2,126·0	1,412,857	58,055	1,805·6	e 1,200,000
Peru	41,636	1,295·0	860,616	58,357	1,815·0	1,206,249	80,369	2,499·6	1,661,234
Uruguay	1,961	61·0	40,540	2,988	71·0	47,187	2,411	e 75·0	49,845
Venezuela	49,191	1,530·0	1,016,838	49,194	1,530·0	1,016,838	49,194	e 1,530·0	1,016,838
EUROPE:									
Austria	2,434	75·7	50,310	2,279	70·9	47,120	2,279	e 70·9	47,120
Hungary	98,677	3,069·0	2,039,657	105,143	3,270·1	2,173,308	105,143	e 3,270·1	2,173,308
France	8,681	270·0	179,442	6,527	203·0	134,914	6,527	e 203·0	134,914
Germany (d)	3,601	112·0	74,435	3,601	112·0	74,435	3,601	e 112·0	74,435
Italy	3,643	113·3	75,301	1,849	57·5	38,215	1,849	e 57·5	38,215
Norway	74	2·3	1,539	86,813	2,700·0	1,794,420	80,812	e 2,700·0	1,794,420
Portugal	7	0·2	150	84	2·6	1,728	84	e 2·6	1,728
Russia	1,159,214	36,056·3	23,963,016	1,072,434	33,354·2	22,167,201	1,258,592	38,988·5	25,911,744
Spain	387	12·4	8,000	377	11·7	7,800	370	e 11·2	7,648
Sweden	3,414	106·2	70,580	3,414	106·2	70,580	2,845	88·5	58,817
Turkey	375	e 11·6	7,751	375	11·6	7,751	648	e 20·0	13,392
United Kingdom	2,845	88·5	58,810	12,760	396·8	263,749	9,664	300·6	199,754
AFRICA:									
Transvaal	3,529,826	109,782·6	72,961,501	348,760	10,846·9	7,208,869	238,991	7,432·9	4,939,944
Abyssinia	20,126	e 626·0	416,000	33,865	1,053·3	700,000	33,865	1,053·3	e 700,000
Rhodesia	54,241	1,687·0	1,127,170	79,854	2,468·0	1,640,251	148,753	4,626·4	3,074,730
Soudan	2,701	e 84·0	55,830	2,701	84·0	55,826	2,701	e 84·0	55,826
West Coast	33,978	1,005·7	702,327	36,284	1,128·5	e 750,000	30,000	933·0	620,100
Madagascar	11,060	e 344·0	228,622	33,471	1,041·0	691,849	36,284	1,128·5	e 750,000
Mozambique	5,416	e 168·4	111,918	8,475	263·6	e 175,176	12,377	384·9	255,840
ASIA:									
Borneo (British)	11,168	347·3	230,850	19,873	616·9	410,038	21,771	677·1	e 450,000
China	273,246	8,501·4	5,650,000	208,031	6,470·1	4,300,000	145,138	4,514·0	3,000,000
East Indies (Dutch)	7,234	225·0	149,527	26,609	827·5	550,000	43,541	1,354·2	e 900,000
India (British)	457,021	14,214·0	9,446,624	512,710	15,946·0	10,597,712	455,870	14,178·2	9,422,555
Japan	53,998	1,679·4	1,116,129	68,485	2,130·0	1,415,598	73,952	e 2,300·0	1,528,580
Korea	70,954	2,206·9	1,466,690	87,882	2,733·3	1,816,525	111,272	3,460·7	e 2,300,000
Malay Peninsula	16,459	512·0	340,200	17,048	530·2	352,382	e 18,000	559·8	372,060
AUSTRALASIA (f)	3,810,130	118,500·0	78,755,372	3,568,279	110,978·5	73,756,325	3,728,057	115,947·8	77,058,928
Unspecified (g)	21,771	677·1	e 450,000	21,771	677·1	450,000	21,771	677·1	450,000
Totals	15,139,140	470,808·7	$312,911,383	12,614,633	392,381·8	260,743,890	12,812,792	398,507·0	264,840,477

(a) Figures based on exports of ores, matte, etc., and coinage. (b) Computed from exports. (c) As reported by the *Statistique de l'Industrie Minerale*. (d) Production from domestic ores. (e) Estimated. (f) Includes six States and New Zealand. (g) Includes Servia, Persia, West Indies, Formosa, British New Guinea and Philippine Islands. (h) Estimate furnished by Mr. George E. Roberts, Director of the United States Mint.

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should be credited to other countries as has been done in the subjoined tables.

PRODUCTION OF SILVER IN THE UNITED STATES.

State or Territory.	1898.		1899.		1900.		1901. (c)	
	Troy Ounces.	Commercial Value. (a)	Troy Ounces.	Commercial Value. (a)	Troy Ounces.	Commercial Value. (a)	Troy Ounces. (b)	Commercial Value.
Alaska	150,000	$87,390	150,000	$89,370	200,000	$122,660	55,000	$32,423
Arizona	2,250,000	1,310,850	2,000,000	1,191,600	1,750,000	1,073,275	2,995,000	1,765,553
California	650,000	378,690	600,000	357,480	1,170,902	718,114	1,118,338	649,257
Colorado	23,502,601	13,692,615	23,114,688	13,771,781	20,386,712	12,472,500	20,833,333	12,281,250
Idaho	6,284,744	3,661,492	4,800,000	2,859,840	6,100,000	3,741,130	4,000,000	2,358,000
Montana	14,818,662	8,633,352	16,850,755	10,039,680	17,300,000	10,610,090	14,000,000	8,253,000
Nevada	800,000	466,080	575,000	342,585	1,300,000	797,290	4,000,000	2,358,000
New Mexico	450,000	262,170	550,000	327,690	550,000	337,315	434,300	256,020
Oregon	128,326	74,763	140,000	83,412	150,000	91,995	125,000	73,686
South Dakota	325,000	189,345	350,000	208,530	210,000	128,793	364,130	214,655
Texas	500,000	291,300	450,000	268,110	525,000	321,983	477,400	281,427
Utah	6,570,256	3,827,773	7,183,107	4,279,695	9,569,188	5,868,780	10,250,000	6,042,375
Washington	275,000	160,215	300,000	178,740	300,000	183,990	350,000	206,325
Others	50,443	29,388	63 284	37,705	100,000	61,330	150,792	88,892
Totals	56,755,032	$33,065,482	57,126,834	$34,036,168	59,561,797	$36,529,250	59,653,788	$34,860,863

(a) The average value in 1898 was 58·26c.; in 1899, 59·58c.; in 1900, 61·33c., and in 1901, 58·95c. (b) Estimate furnished by Mr. George E. Roberts, Director of the United States Mint.

SILVER PRODUCTION OF THE WORLD.

Countries.	1900.			1901.		
	Troy Ounces.	Kilograms.	Commercial Value.	Troy Ounces.	Kilograms.	Commercial Value.
America, North:						
United States	59,561,797	1,852,564·4	$36,529,250	59,653,788	*f* 1,855,425·6	$34,860,863
Canada	4,468,225	138,976·2	2,740,362	5,078,318	157,952·1	2,993,668
Mexico (a)	55,804,420	1,735,697·7	34,224,851	55,152,340	1,715,416·0	32,512,804
Central America	1,446,795	45,000·0	887,319	1,072,095	33,345·6	632,000
America, South:						
Argentina	383,561	11,930·0	235,238	383,561	*e* 11,930·0	226,109
Bolivia	10,492,685	324,490·4	6,398,366	9,329,941	*e* 290,191·3	5,500,000
Chile (b)	5,772,791	179,552·4	3,540,453	5,772,789	*e* 179,552·4	3,403,059
Colombia	2,800,000	87,089·0	1,717,240	2,520,000	78,380·1	1,485,540
Ecuador	81,000	251·9	49,677	84,818	2,638·1	50,000
Peru (a)	6,590,955	205,000·0	4,042,433	6,655,257	*e* 207,000·0	3,923,274
Europe:						
Austria	1,272,279	39,572·0	780,269	1,272,279	39,572·0	750,008
Hungary	649,511	20,201·9	398,345	649,511	20,201·9	382,687
France	452,268	14,067·0	277,376	452,268	*e* 14,067·0	266,612
Germany (c)	5,412,589	168,349·0	3,319,028	5,412,589	*e* 168,349·0	3,190,721
Greece	1,011,856	31,472·0	620,571	1,011,856	*e* 31,472·0	596,489
Italy	1,002,115	31,169·0	614,597	1,002,115	*e* 31,169·0	590,746
Norway	147,895	4,600·0	90,704	147,895	*e* 4,600·0	87,184
Russia	112,175	3,489·0	68,797	112,775	*e* 3,489·0	66,127
Servia	18,386	570·0	11,276	18,326	*e* 570·0	10,803
Spain	5,909,418	183,802·0	3,624,246	5,909,418	183,802·0	3,485,602
Sweden	61,955	1,927·0	37,997	61,955	*e* 1,927·0	36,522
Turkey	429,286	13,352·0	263,233	65,363	*e* 2,033·0	38,531
United Kingdom	190,850	50,936·0	117,048	167,000	*e* 5,194·2	98,447
Asia:						
Dutch East Indies	73,690	2,292·0	45,194	73,690	*e* 2,292·0	43,440
Japan	1,895,398	58,953·0	1,162,448	1,895,398	*e* 58,953·0	1,117,337
Australasia	14,063,244	437,412·3	8,624,988	10,848,420	337,420·9	6,395,144
Other countries (d)	48,226	1,500·0	29,577	48,226	1,500·0	28,429
Totals	180,093,364	5,599,216·2	$110,451,012	174,851,391	5,438,443·2	$102,769,702

(a) Statistics compiled from exports and coinage. (b) Exports of silver in all forms. (c) Silver produced from domestic ores only. (d) The output is mostly from China and Persia. (e) Estimated. (f) Estimate furnished by Mr. George A. Roberts, Director of the United States Mint.

NOTE.—Unless specified to the contrary, the statistics have been taken from official sources or have been collected directly from the producers by THE MINERAL INDUSTRY. The average commercial value of silver for 1900 was 61·33c. per ounce, which is equivalent to $19·718 per kilogram. The value for 1901 was 58·95c. per ounce, equivalent to $18·953 per kilogram.

Gold and Silver Mining in the United States during 1901.

The production of gold and silver for the years 1901 and 1900 may be obtained from the detailed tables in the early part of this section.

Alaska.—(By William M. Brewer.)—Since the discovery of gold in the Klondike, the attention of prospectors has been directed to the numerous islands of Alaska and to the coast line from Portland Canal to Behring Sea. From Ketchikan as the central point, exploring parties have followed the coast lines and penetrated into the interior of Prince of Wales, Revillagigedo, and the smaller islands in search of ore deposits. As a result of this search deposits of auriferous quartz have been found at Hollis at the head of Cassau Bay and on Karta Bay, Prince of Wales Island, also on Thorne Arm in Revillagigedo. At the latter locality the quartz occurs in a belt of schistose rock, which apparently occupies an extensive zone in southeastern Alaska. Extensive mining operations have been conducted for some years at Berner's Bay on the mainland, northwest from Port Wrangel. In the Porcupine district, inland from Pyramid Harbor, placer gold was discovered in 1899, and the deposits have been worked since that date. There seems to be a good future for the mining industry in the southeastern portion of Alaska, as this part of the territory has the special advantages of mildness of climate, cheap transportation and low cost of fuel and supplies.

Nome District.—During 1901 mining was much handicapped by litigation over claim titles, as well as by the shortness of the working season, which was fully two months late, and closed at the usual time in the fall. Drilling operations on the tundra which were commenced in 1900 continued throughout 1901, and resulted in the discovery that a large part, if not all, of the gravel underlying the tundra will pay to work. The tundra, or moss, is about 8 ft. deep, and between the tundra and bed-rock is a layer of gravel from 40 to 80 ft. deep which bears gold in quantities varying from a few cents to $12·50 per cu. yd. After bed-rock is reached it is estimated that by using a 6 to 8-H.P. boiler for thawing, with 4 gangs of 3 men each, the average cost per cu. yd., including coal, will be $8·50. A New York company pursued investigations with a Keystone boring drill during the entire season, winter as well as summer, and found that the gravel was not frozen below the tundra, that the tundra itself could be used for fuel, and that the values ranged from $3·64 to $12·41 per cu. yd. The bench claims of Anvil creek proved even richer than the creek claims: Dry, Extra Dry, Bourbon, Dexter, Buster, Mountain, Rock, Specimen, Nikola, and Snow were large producers, while smaller creeks are rapidly becoming payers. Three bench claims on Glacier creek have discovered the old channel on their property, and are very rich. Owing to their inland position, and the frozen condition of the country, the Koogrock, Bluestone, and Casa de Pogra districts have not been developed to the point of rivaling Nome as had been expected. Outside of Anvil creek, Ophir creek in the Eldorado district, which probably has more paying claims in proportion to its length than any in Alaska, together with its tributaries, has produced over $1,000,000, despite the shortness of the season. Of the new districts Good Hope Bay and Candle creek are being vigorously boomed, but authentic information of the amount of gold obtainable is lacking. In the Solomon river country several

dredging plants are expected to be in operation in 1902 on the low-grade gravel deposits which are of immense size. The development of the deposits in the vicinity of Nome has been and will be much handicapped by the governmental policy of permitting claims to be staked by proxy. Especially in the creek claims, assessment work is often falsely reported as accomplished and as evidence is obliterated with the spring rains, much deception is practiced; even the bench claims are not free from suspicion. But as relocation involves a lawsuit, several years will elapse before all the older deposits are thoroughly explored.

Juneau and Other Districts.—The Alaska Treadwell Gold Mining Co. mined and treated 457,802 tons of ore for a yield of $559,126 ($1·22 per ton) in free gold and $301,611 (66c. per ton) in sulphurets, a total of $860,737 or $1·88 per ton. In addition there were on hand at the close of the year 845 tons of sulphurets valued at $35,422, which brought the total gold production up to $896,159 or $1·96 per ton as compared with $1,153,368 or $2·07 per ton in the preceding year. The total working costs were $483,319 ($1·0557 per ton) and the construction expenses amounted to $62,649 (13·69c. per ton), while the net profits were $352,559 (77·01c. per ton). Dividends amounting to $300,000 or 6% on the capital stock were paid and the remainder of the profits carried over on the surplus account. The estimated amount of ore in sight and available for the mill on May 15, 1901, was 3,917,589 tons. The Alaska United Gold Mining Co., owning the Ready Bullion (120 stamps) and the 700-Foot (100 stamps) mines adjoining the Alaska Treadwell on Douglas Island, reports for the year ending December 31, 1901, as follows: the Ready Bullion milled 171,642 tons of ore averaging $2·01 per ton in value for a yield in gold of $1·3096 per ton free, and $0·6326 per ton in sulphurets. Total costs including construction account was $1·8574, leaving a net profit of $0·0848 per ton. The 700-Foot mine stamped 89,840 tons of ore averaging $2·21 per ton for a yield in gold of $1·0105 per ton free, and $0·4849 per ton in sulphurets. Total cost, including construction account, was $1·9738 per ton, produced at a net loss of $0·4785 per ton. The total receipts for bullion from both mines was $465,184; total operating expenses, including interest and coal shortage, was $504,649, showing a net loss of $39,465 for the year. The amount of ore blocked out in both mines at the close of the year was 527,604 tons. The Rodman Bay mines on Baranoff Island, 60 miles from Sitka, are being developed by an English company. An 8-mile railway and a 150-stamp mill, which will be completed in 1902, will enable the company to work profitably its immense low-grade gold deposits. The ore ranges from $3 to $4 per ton in gold. The Olympia Mining Co., on Woewadski Island (near Wrangel) during the year operated a 20-stamp mill on ore yielding $7·50 per ton. The Yellow Jacket Co., owning four quartz claims on Windham Bay, completed a wagon road 1·5 miles long to its property, and has a 10-stamp mill en route.

Alabama.—There was a small production of gold in 1901 which came from the mines in the Arbacoochee district of Cleburne and Randolph counties.

Arizona.—There was considerable activity in Yavapai County, especially about Wickenburg and Congress and in the region east of Prescott. An important development has been the construction of the Poland-Lynx Creek tunnel which when completed will give improved transportation facilities to the

Lynx Creek district and will also form an outlet for the Poland-Hamilton mines. The workings of the Congress mine have reached 3,250 ft. in depth, but the output is still well maintained. The Mud Hole mine, which is operated by the Penn Mining Co., has increased its plant to 120 tons daily capacity. Some good strikes were reported in the Chloride district which gave increased impetus to development operations. Tombstone may once more be an important mining center, as the consolidation of the mines will facilitate their development on a larger scale. There was considerable activity shown in prospecting in Cohise and Pima counties and numerous deposits are being developed some of which carry gold and copper. The Rio Del Monte mine near Harqua Hala has commenced the erection of an 80-stamp mill, and a large cyanide plant is in process of construction at Gold Basin. With the renewed interest that is shown in the mining industry, it seems probable that the Territory will give an increased output of gold in 1902.

California.—The gold mining industry showed some expansion despite the unfavorable conditions of rainfall that prevailed in 1901 as in the two preceding years. With a normal water supply the output would have been largely in excess of that of 1900, as a great many of the old mines were prepared under favorable circumstances to extend their operations, while the number of new producers would have been increased. The use of the steam dredge for working low-grade river gravels has proved a success in several localities, particularly on the Feather, American and Klamath rivers and the number of plants in successful operation is being increased. Large tracts of land have been purchased around Oroville and other points where the conditions are favorable for this class of work. In Butte County alone there were 12 companies engaged in active operations during 1901, while the total for the State was 25 companies with 26 dredges constructed and eight to be built. The actual capital invested in the industry is said to be not far from $2,500,000. The types of dredges used include the Risdon, Eucyrus, Urie, and Marion. Hydraulic mining was carried on in the drainage basin of the San Joaquin and Sacramento rivers, but the center of this industry has been transferred to the northern part of the State, where the laws are not so rigorous in regard to the impounding of tailings. The conditions here are very favorable for hydraulicking, enabling low-grade gravels to be worked at a profit. One company operated during the year 1900 at the phenomenally low cost of 2·2c. per cu. yd.

Colorado.—This State which for several years has occupied first place in the output of gold, produced 1,339,112 oz., valued at $27,679,445 in 1901 against 1,391,486 oz. and $28,762,036 in the preceding year. The output of silver amounted to 18,492,563 oz. against 20,336,712 oz. in 1900. Teller County continued far in the lead as a gold producer, while Lake, San Miguel, Gilpin, and Ouray counties followed in the order named. The Cripple Creek district of Teller County increased its tonnage of ore shipped but the value of the product was somewhat less The smaller mines in this district did not contribute as much as usual to the total, while some of the large producers were hampered in their operations by water, and the necessity of giving increased attention to development work. Stratton's Independence, Ltd., from November 28, 1900 to Septem-

ber 20, 1901 produced 66,199 tons of shipping ore with a gross value of $2,506,862, from which a profit of $1,067,000 was realized. These totals were in excess of the estimates made by Mr. John Hayes Hammond, under whose direction a large amount of development work was carried on, resulting in an increase of ore reserves and important economies in working costs. The main shaft was sunk 400 ft., while 7,288 ft. of drifts and cross-cuts were run, the total expense of the development work being $213,740. No payable ore bodies were found below the 1,150-ft. level, but it was deemed advisable to prosecute the work inasmuch as some of the neighboring properties have shown zones of pay ore succeeding poor ones in depth. The Portland Gold Mining Co. reported a production during the calendar year 1901 of $2,408,413, from which a profit of $1,760,939 was earned. Other mines which were active and important producers during the year were the Gold Coin, Elkton, Doctor-Jack-Pot, and Gold King. It is thought that the lower rate of treatment charges on low-grade ores that was conceded by the mills and the reduction of freight charges by the railroads will react favorably upon the output in 1902. In the Leadville district, the year's operation resulted in the extension of the gold producing territory. The Smuggler-Union Mining Co. in San Miguel County was handicapped by a strike of the union workmen which lasted from May 1 to July 7, and by the destruction by fire of buildings at the Bullion tunnel. Important improvements were undertaken, including the construction of a cyanide plant of 400 tons daily capacity and the rebuilding and enlargement of one of the two mills at Pandora. The company shipped 23,799 oz. bullion to the mint and 10,792 tons of ore and concentrates to the smelters. The holdings of the Tomboy Gold Mines, Ltd., were increased by the purchase of claims carrying the Argentine claim, and it is proposed to build a new mill and make other improvements during 1902. For the year ending June 30, 1901, the company's report showed an output of $649,281 bullion from which after paying all charges a profit of $218,585 was realized. The new chlorination mill now building for the Portland Co., at Cripple Creek, is expected to be in operation before the middle of 1902. The mill will contain heavier crushing machinery than usual, three 60-ft. diameter Pearce turret furnaces—the largest ever built—and twelve 10-ton chlorination barrels; all buildings are steel construction, and the capacity of the plant will range from 450 to 500 tons per day. A consolidation of eight mining companies of Cripple Creek along the line of the United Mines tunnel (now 9,462 ft. in length) has been effected by the Woods Investment Co. The new company is capitalized at $5,000,000, divided into $1 shares.

Georgia.—The Dahlonega Consolidated Gold Mining Co. has employed about 100 men at its mine and mill on the Hand property during 1901. Considerable shafting and drifting was done during the year, resulting, according to report, in the blocking out of considerable bodies of ore ranging from $8 to $12 per ton in gold. Neither the plates nor the concentrators seemed to catch the fine gold, the recoveries from ore of $10 per ton ranging from $2 to $3, and after successful experiments the company began the erection of a Hicks barrel process plant. Early in 1902 the Dahlonega Gold Mining & Milling Co., of Chicago, Ill., capitalized at $2,500,000, was organized to operate placers and quartz veins on

its 710-acre tract. The company proposes to build a 50-stamp mill. In May, 1901, announcement was made of the organization of the Georgia Dredging Co., capitalized at $500,000, for the purpose of operating gold dredges on the Etowah river. Several dredging companies were in successful operation on the Chestatee river during 1901. Experiments were made with a suction pump to work such river bottoms as are filled with jagged rock, and also the saving of the black sands said to contain from $20 to $100 per ton in value was attempted. The Columbia Gold Mining Co., of McDuffie County, milled 1,146 tons of ore during 1901 for a yield of $7,272.

Idaho.—The gold mining industry was fairly successful in this State during 1901 and the output showed a moderate increase to which both alluvial and quartz mining contributed. The finding of gold at Thunder Mountain, near the central part of the State, created considerable excitement, but as the discovery was made late in the year, no extensive developments were possible, and the value of the ore bodies is still unproved. According to the best authenticated reports, there is a large mass of low grade material which contains some good pay streaks. The values are disseminated through the rock, apparently forming no well defined lodes. At the De Lamar mine, work on the tunnel was suspended about the middle of the year, but prospecting was continued by diamond drill which located a small ore body that still awaits exploration. As the end of the ore reserves had been practically reached, the operations during the year were of limited character. Dredging on Snake river has become an established industry. The Sweetser-Burroughs Mining Co. has two boats in operation near Minidoka, one of which was built in 1894 and the other in 1899. According to Robert Bell (*The Engineering and Mining Journal,* February 15, 1902) the cost of handling the river gravel ranges from 4·5c. with the suction dredge to 5·5c. with the chain elevator bucket type. The method employed in saving the gold consists in discharging the gravel onto a stationary sluice from which it passes to two stationary sluices with perforated steel bottoms with 0·125-in. holes. The coarse materials from the screens is carried on a rubber belt to the stem of the boat, where it passes into the river. The fine material is discharged into a distributing box which feeds it evenly to a set of burlap tables which discharge over the side of the boat. The burlaps are taken up at intervals of six or eight hours and washed in a wooden tank, from which the accumulated gold and black sand concentrates are elevated automatically to the amalgamating room, where the gold is amalgamated and retorted.

Montana.—The Fergus Co. mines produced actively during the year and several new plants were erected. Large cyanide plants were erected in Lewis and Clarke counties, as described elsewhere in this volume under the caption "Review of Progress of Cyanide Industry during 1901." A number of small stamp mills were erected and put into operation in Madison County. In Granite County a 600-ton concentrator equipped with Brückner chloridizing roasters, and pan-amalgamation plant, the whole to be operated by electricity, was completed during the latter part of the year. The report of the Montana Mining Co., Ltd., for the year ending December 31, 1901, shows a total of 25,122 tons of ore treated for a yield of $122,131, at a cost for mining, milling, and prospecting of $231,555,

the operation for the year resulting in a loss of $109,424. During the year 96,303 tons of tailings were treated for a yield of $247,560 in gold and silver, at a cost of treatment and handling of $102,117, resulting in a profit of $145,443. Deducting the loss in stamping, the profit for the year was $36,019. No dividends were declared, but the Lucky Girl group of mines, at Edgemont, Nev., was purchased at a cost for mines and equipment of $158,690, which was paid for from accumulated surplus. A large cyanide plant will be erected on the property. The most important purchase of mining property during the year took place in September, when the Boss Tweed and Clipper group of mines at Pony, Madison County, was bought by A. C. Burrage, of Boston, for $600,000; a 100-stamp mill is in course of erection on the property which has an immense tonnage of low-grade gold ore having a width of 90 ft.

Nevada.—The development of the Tonapah Lake district, in Nye County, by a system of small leaseholds has proved a bonanza for the lessees. Their shipments for the year aggregated $1,000,000 of ore averaging $187 per ton, and some 30,000 tons of ore worth $125 per ton remain on the dumps awaiting shipment. The ore is very siliceous, and for smelting requires the addition of 1·25 tons of iron, copper, or lead ore, to 1 ton of Tonapah ore. The ratio of gold to silver in the ore is approximately 1 to 2. Test runs made in stamp mills on the Carson river claim a saving of 88·5% of the gold and silver values. The company owning the mine has cancelled the leaseholds and proposes to have a 20-stamp mill in operation early in 1902. It is estimated that the Tonapah Mining Co. of Nevada, which purchased the mines early in 1901 for $336,000, has received during the year, its entire purchase price in royalties. The 100 lessees have blocked out large bodies of ore which they were unable to remove. Transportation facilities are lacking, ore and supplies must be hauled by wagon, and for a long time water was sold for $1 per barrel. Springs are being piped to the camp of 1,200 inhabitants which has sprung up during the year, and wells have been sunk with the result that water is now available. At Ely, in White Pine County, the Chainman Mining & Electric Co. has completed a 150-ton wet crushing cyanide plant, containing the following machinery: Gyratory crusher, 1 set roughing rolls, 2 Chilean mills, 400 ft. amalgam-plates, 8 Cammett concentrators, 4 settling tanks 26 ft. square, 8 leaching tanks 28 ft. square, 2 vacuum pumps, 2 solution pumps, 2 filter presses, and 1 air-compressor. The De Lamar zinc-dust precipitation process is provided for and a complete refinery installed. The daily capacity of the mill is 225 tons of slimes. The plant is equipped to run by electricity from Ely, two miles distant. It is said that the ore yields $2·50 to amalgamation, 1 ton of $100 concentrates from 100 tons of ore, and the balance to the cyanide.

North Carolina.—(By Joseph Hyde Pratt.)—There are at present about 15 mines in operation located in Cabarrus, Mecklenburg, Stanly, Montgomery, Burke and Rowan counties. The principal developments have been confined to the vicinity of Gold Hill, Rowan County, about 14 miles S.E. of Salisbury. The region is made up of chlorite and argillaceous schists which are cut by diabase dikes and enclose bands of schists impregnated with auriferous pyrite and quartz veins and stringers. The Whitney Reduction Co. has been developing its property for

two years. Its property embraces 30,000 acres of mineral, farming, and river lands. Three shafts, one of which is 600 ft. deep, have been sunk, and a 10-stamp mill and chlorination plant have been making test runs for a year. The proposed power dam on the Yadkin river, 14 miles distant, will be erected in two years' time, and the company will then erect a 100-stamp mill. The Gold Hill Co. has erected a 20-stamp mill and made all preparations to treat the large body of ore blocked out in the old Randolph mine. Among the other producers of gold in 1901, are the Parker mine in Stanly County, the Champion mine in Mecklenburg County, and the Martha and Mills mines in Burke County.

Oregon.—The gold yield for 1901 from the mines in the vicinity of Sumpter, Baker County, is estimated at over $3,000,000. The ore is quartz carrying considerable pyrites, but is easily mined and milled, and the cyanide process saves a large per cent. of the gold. One of the most promising new properties is the Oregon King, directly south of the North Pole, and Golconda, two of the largest producers in the district. The Oregon King will erect a 10-stamp mill and cyanide plant for the tailings, besides putting in a giant to work their placer ground. The Old Channel Co., in Josephine County, has widened its 12-mile ditch to a capacity of 5,000 miners' inches, and with four giants has reduced the cost of handling gravel to 2·5c. per cu. yd. The Stirling Co., on Forest creek, gets its water to operate two giants for 9 months in the year, from a 25-mile ditch carrying 2,500 in. of water from Glade Fork. The gold is found in a red clay gravel deposit.

South Carolina.—(By Joseph Hyde Pratt.)—The chief source of the gold produced in this State is the Haile mine in Lancaster County about three miles N.E. of Kershaw. A 60-stamp mill, 20 concentrators and a chlorination plant are in operation, and the mine is well developed. The ore bodies are lenticular in shape and carry both free gold and auriferous pyrite. At Abbeville somewhat similar ore bodies are being worked by the Kendricks Gold Mining Co.

South Dakota.—The principal feature of the mining industry in the Black Hills was the starting up of a number of new cyanide plants for treating low-grade refractory ores and mill tailings. The increment of production from these sources cannot be ascertained with any degree of accuracy, but doubtless it was considerable. One of the largest plants having a capacity of 1,200 tons per day was put in operation by the Homestake Mining Co. and proved a financial success from the beginning, as did the smaller plant of the Fortland Co. For details relative to the cyanide process as used in the Black Hills the reader is referred to the review of this subject by Charles H. Fulton on page 339 elsewhere in this volume. Construction work was started late in the year on a new smelter at Rapid City which will have a daily capacity of 500 tons. The report of the Homestake Co. for the year ending June 30, 1901, showed a return of $3,569,205 in bullion, or $3·82 per ton of ore, which was 20c. less per ton than in the preceding year. The total expenses were $3,296,517, leaving a balance of $421,566 after including receipts of $48,305 for concentrates sold, $2,772 for siliceous ore and $78,851 from other sources. The dividend distribution during the fiscal year was $1,260,000. Dr. C. C. O'Harra, in a paper read before the International Congress, at Boise, Idaho, July, 1901, classifies the gold deposits of the Black

Hills into (1) Recent placers. (2) Cambrian cement or conglomerate. (3) Auriferous quartz veins, in the Algonkian slates. (4) Impregnated zones in the Algonkian schists and slates and (5) siliceous ores of the Siluro-Cambrian and Carboniferous series. Of these classes, one and two have been practically exhausted, class three is now receiving much attention, the ores being found S.W. from Deadwood around Bald Mountain and of lesser extent in the galena district, S.E. from Deadwood. The ore veins occur in extended lenticular masses running north and south and of a thickness up to 15 ft., a width up to 200 ft., and often more than a mile in length. Narrow vertical fissures filled with ore continually follow the general trend of the flat ore bodies and frequently extend into the overlying shales and the underlying quartzite. The chief horizon is just above the quartzite near the bottom of the Cambrian series. The value of the Siluro-Cambrian ores ranges to $60 or more in gold and some silver, averaging in total value from $15 to $20. Ore less than $10 is generally not worked. The annual production of gold in the Black Hills has continually increased during the past few years, owing to two causes: first, the increased development of the siliceous ores both in the Siluro-Cambrian, the most extensively worked, and in the Carboniferous, the most recently discovered, through the development of the cyanide process for treating the ores; and second, by the considerable enlargement of the Homestake plant, now the largest cyanide plant in the district operating on the tailings formerly allowed to waste. The silver output remains uniform, being approximately $100,000 for the year. The chief localities are those of Carbonate, Galena and Spokane, carbonates, chlorides and sulphides are the chief ores.

Tennessee.—The placer deposits of Coker creek, Monroe County, were operated by four or five companies with some success. One company has done some exploration work on quartz veins carrying free gold, but the ore has not been treated on a commercial scale.

Utah.—The Consolidated Mercur mill treated 282,000 tons of ore, shipped 72,222 oz. gold during the year, and employed an average of 520 men in mine and mill. In Piute County, the Annie Laurie mine on Gold Mountain produced for its owners, the Western Exploration Co., $401,391, about 20% of which was silver and the balance gold. The cyanide mill treats about 150 tons of ore per day, and 125 men are employed in mine and mill. The Ophir Co., in the State-line district, Iron County, completed its 100-ton mill to treat ore by the Russell process. The mill is equipped with a Gates rotary crusher, a revolving dryer, two 14×26-in. Gates rolls, one 15×36-in. roll, 4 revolving screens, and 2 White & Howell roasters. The engine-room contains a 150-H.P. Corliss engine, a 10-drill air compressor, and an engine for the dynamo which lights the mine and mill; two 80-H.P. boilers furnish steam. The mill was not finished until late in the year, and results are not obtainable. The report of the Horn Silver Mining Co. shows a total shipment of 8,464 tons of ore and 2,766 tons of concentrates during 1901, from which was derived a net revenue of $206,227. Dividends amounting to $72,000 were paid and $87,448 carried forward. The ores contained 3,204 net tons lead, 577,578 lb. copper, 277,382 oz. silver, and 504 oz. gold, besides a large percentage of zinc. Water shortage during the year greatly

hampered the working of both mine and mill. During 1901 the Daly-West Mining Co. milled 57,773 dry tons of ore and 8,798 tons of tailings, producing 12,926 dry tons of concentrates which sold for $409,591. Shipments of 18,418 dry tons of crude ore, and 733 tons of oxides, realized $694,221, and $9,417, respectively, making the total receipts from ore sales $1,113,229. The net revenue amounted to $892,489, from which dividends of $607,500 were paid, and $13,846 expended in mine and mill construction, with cash carried forward, $271,143. The total metal content of the ores were copper, 1,326,448 lb.; lead, 7,793 tons; zinc, 5,466 tons; gold, 1,607 oz.; and silver, 1,755,454 oz. The Utah Consolidated Gold Mines, Ltd., which owns the Highland Boy mine, reports for the latter a production for the year of 13,983 oz. gold and 176,331 oz. silver from 167,947 tons of ore treated at the company's smelting and Bessemerizing plant. Besides this amount of ore, 1,651 tons of matte was converted for the Bingham Co., from which was produced 2,931 oz. gold, and 100,068 oz. silver. The total receipts for the year were $1,944,594 and the total expenses were $1,312,110, leaving a balance of $632,484, from which dividends amounting to $615,975 were paid. In 1901 the Quincy Mining Co. produced from 39,209,925 lb. of dry ore, 984,169 lb. copper, 9,826,007 lb. lead, 1,650,738 oz. silver, and 1,568·4 oz. gold. On April 1, 1902, the Quincy Mining Co. sold its property to the Daly-West Mining Co.

Virginia.—The output of gold in 1901 was limited to the placer deposits in Floyd County and amounted to about $550. Some development work was done on the John's Creek mine in Grayson County and on the Herd mine in Patrick County.

Washington.—The production of gold in the State of Washington has been very much restricted for the year, owing to the complete stoppage of operations in the Republic district. The Republic Consolidated Gold Mining Co. suspended operations in June, due to the complicated financial outlook as well as the apparent failure of its veins with depth. The Republic Power & Cyaniding Co. shut down in July owing to insufficient ore supply. While this mill was successful, both metallurgically and financially when running full, operations on a reduced scale were not profitable. A detailed description of the working of this plant will be found elsewhere in this volume under the caption "Review of Progress of the Cyanide Process during 1901." In King County, the Seattle Smelting & Refining Co. has erected a plant for refining silver and gold, particularly Alaska gold dust. The works are at Interbay, Seattle. The California mine of Ferry Co., Republic mining district, made some shipments to the Granby smelter, at Grand Forks, B. C. The ores assay very high in gold and carry some silver and copper. The Silverton mining district of Snohomish Co., developed some activity with the re-building of the Everett & Monte Cristo Railroad, which was washed out and practically destroyed in 1897. Development and assessment work progressed steadily if slowly. The Forty-five mine repaired its 2·5 mile overhead tramway to the railroad. The ore is largely galena, pyrite, and ruby silver in slate. In past years 800 tons of sorted ore have been shipped, but without much profit.

Wyoming.—Gold mining has not materially changed during the year. Early last spring there was great activity in the Sweetwater district and several old

properties were opened and considerable ore taken out and crushed. This activity almost ceased with the approach of winter. As usual the Carissa mine was the largest producer. In other localities considerable prospecting was done with indifferent results. In the Medicine Bow Mountains some of the old producers changed hands and new companies expect to commence work during the coming year. The gold production of the State has not increased over the previous year.

GOLD AND SILVER MINING IN FOREIGN COUNTRIES DURING 1901.

NORTH AMERICA.—*Canada.*—The larger part of the output of gold in Canada in 1901 came from Yukon territory. According to William T. Robertson, Provincial Mineralogist, the production of British Columbia in 1901 was divided as follows: Placer gold, $970,100; lode gold, $4,343,603; a total of $5,313,703, against $4,732,105 in 1900. The Ontario mines yielded in 1901, $244,443 in gold, while in Nova Scotia the production in 1901 was $604,500.

British Columbia.—(By W. M. Brewer.)—The occurrences of free-milling gold ores so far discovered in the Province, have been confined to the Ymir district, near Nelson, Camp McKinney, the Lillooet district near the Fraser river north from the Canadian Pacific railroad, and the Atlin district in the northwestern portion of the Province. It appears somewhat remarkable that notwithstanding the large quantities of placer gold mined from the Fraser river, Granite creek, Thompson river, the Omenica and Cassiar countries in the northern portion of the Province, the discoveries of free-milling gold-bearing quartz have been so few. It is noticeable that a straight line drawn on the map from Granite creek, in the Similkameen country to Douglas Island, Alaska, approximates very closely to the trend of the geological formation or country rock, and that from every prospected stream crossed by the line placer gold has been mined. It would appear from the results of prospecting at various points along this line that a gold-bearing zone with its narrowest portion in the southern part of the Province, maintained continuity the entire distance. Northward of Camp McKinney and Fairview to the Bridge river portion of the Lillooet district, a distance of nearly 300 miles, very little prospecting for gold has been done, and from there to Atlin, except on the Skeena, Naas and Stikene rivers and their tributaries, the country is to all intents and purposes unexplored, although the tributaries of the rivers mentioned yielded good pay from placer mining as early as 1860. The most successful of the free-milling propositions has been the Ymir mines near Nelson, where an 80-stamp mill and a cyanide plant are in operation treating an average of about 200 tons of ore per day, so satisfactorily that this mine ranks among the large dividend payers of the Province, having paid $200,000 in dividends during the year. The chief feature of interest in 1901 was the cutting through of a large ore body on the fourth level, which is reported to carry $40 a ton in values. The prospects are very encouraging as to the future development of the mine. The Cariboo, Camp McKinney, has also paid about $300,000 in dividends, operating with a 20-stamp mill and concentrating tables, the concentrates being shipped to the Greenwood smelter by wagon road.

The Atlin district has been seriously handicapped by the passage of the Alien

Act in the spring of 1899, by litigation over titles and water rights, and by shortage of water. However, this portion of the Province ought to show considerable progress during 1902, because the large hydraulic plants are all installed and the ground has been prospected to such an extent that operators will be enabled to prosecute their work vigorously. The value of the lode claims which have been discovered in the Atlin district is still undetermined. Some very persistent veins of auriferous quartz have been partially prospected on Munro Mountain and Pine creek, as well as on the mountains near Taku Arm. A very extensive deposit of low-grade gold-bearing material also occurs in the vicinity of Atlin City, where the magnesian country rock is traversed by innumerable veinlets of quartz, some of which carry quite high values in free gold. As much of the country rock itself carries values, it would appear that the gold-bearing quartz had been broken down by erosion and the gold becoming free, had settled into the porous portions of the magnesian rock.

Vancouver and Texada Islands, which are included in the Coast districts, have furnished the entire output under that head. Although several properties on the coast of the mainland have been developed to the point where shipments may be made from them during 1902, yet they made no production during 1901. The product from the Coast represented the output of the Lenora mine on Mount Sicker, Vancouver Island, and the Cornell and Marble Bay mines on Texada Island. The Nahmint Mining Co., owners of the Three Jays mine on the west coast of Vancouver Island, commenced shipping in December, 1901. This is the most extensively developed property in the Coast district, having been proven by a series of tunnels, drifts, upraises and winzes to a depth of 700 ft. below the summit of the outcrop.

The Le Roi Mining Co., Ltd., in the Rossland district, reports for the fiscal year ending June 30, 1901, a production of 202,583 tons of ore, averaging 0·35 oz. gold, 0·6 oz. silver per ton, and 1·33% Cu. Owing to labor troubles in the Northport smelter the mine was closed from July 12 to October, 1901. The appended table gives the production, metallic contents, and values of ores produced from 1894 to 1901.

OUTPUT OF TRAIL CREEK MINES FROM 1894 TO 1901.

Years.	Tons of Ore.	Gold. Oz.	Value.	Silver. Oz.	Value.	Copper. Lb.	Value.	Total Value.
1894.....	1,856	3,723	$59,568	5,357	$3,214·20	106,229	$12,788·64	$75,520·64
1895.....	19,693	31,497	602,957	46,702	27,021·20	840,429	72,385·80	702,359·00
1896.....	88,075	55,275	1,104,500	89,285	59,830·00	1,580,635	79,030·00	1,243,360·00
1897.....	68,804	97,024	1,940,480	110,068	65,821·00	1,819,586	90,079·00	2,007,280·00
1898.....	111,282	87,343	1,746,861	170,804	94,539·00	5,282,011	629,411·00	2,470,811·00
1899.....	172,665	102,976	2,127,482	185,818	105,173·00	5,698,889	996,431·00	3,229,086·00
1900.....	217,636	111,625	2,306,172	167,378	97,648·00	2,071,865	335,495·00	2,739,300·00
1901.....	283,360	132,333	2,735,323	970,460	543,458·00	8,333,446	1,342,518·00	4,621,299·00

Dawson.—The output of gold from the Yukon region in 1901 according to official authorities was $18,000,000, a decrease of $4,275,000 from the previous year's record. The exhaustion of some of the very rich deposits on Eldorado and Bonanza creeks was responsible for this unfavorable showing, and it seems probable that the phenomenal discoveries that were made in other parts of the district will soon be worked out. Whether the future will show a continued decrease of

production depends largely upon the progress that is made in adopting improved machinery and more economical methods of working. Cheaper transportation is also one of the essential requirements for the future and its importance is recognized by the Dominion Government which has recently mapped out and begun the construction of an extensive system of roads connecting the most important mining creeks with Dawson. It has been stated that the cost of transporting machinery from Dawson to adjacent claims frequently has exceeded by from three to ten times the original cost of the machinery at Vancouver. During the past year some improvements were made in mining methods, more particularly in the wider use of steam apparatus for thawing the frozen gravels, this being done usually by wood fires. Pulsometer pumps were tried for this purpose, and gave such favorable results that they will probably come into more general use. On Hunker creek hydraulicking has been attempted, and a single river dredge has been in operation on Bonanza creek. One of the most important events of the year was the erection of a stamp mill in the vicinity of Dawson which started crushing in November. It is stated that sufficient ore has been mined to keep it running for some time to come.

Nova Scotia.—The production of gold during the fiscal year ending September 30, 1901, was 30,537, against 30,399 oz. for the previous year. An unusually dry summer hampered operations in the field, causing some of the mills to close down for several weeks. The Baltimore & Nova Scotia Mining Co. purchased the Guffy-Jennings mine and added a new cyanide plant and a 40-stamp mill to the equipment. The St. Anthony mine, which is located on a vein 8 in. in width, produced 1,289 oz. gold from 1,281 tons of ore.

The Brookfield Mining Co. at North Brookfield during the latter part of 1901 sold its property to a New York syndicate. Its 800-ft. shaft is the deepest in Nova Scotia. The plant comprises a 20-stamp mill and a chlorination plant, and about 70 men are employed. The Fouquoy mine in Moose River district discovered a new ledge of ore nearly 14 ft. in width, the first 56 tons extracted yielded 396 oz. of smelter gold. The Waverly Gold Mining Co. operated its mine successfully during the year. The result of cynaniding tailings with a small plant in the Cariboo district is reported as a return of 330 oz. in gold from 5,495 tons treated, with final clean-up, yielding over $2 per ton.

The Richardson mine at Goldboro completed during 1901 a railway 10,000 ft. in length, connecting its wharf with the mine. The elevation from wharf to mine is 200 ft. and the motor is a combined traction engine and hoist of 16 H.P. capacity. An addition of 20 stamps to the mill brings the total to 60 stamps milling 120 tons of ore per day. The average yield by amalgamation is $3 per ton.

Ontario.—The Sultana Gold Mining Co. in the Lake of the Woods district during the year operated its 20-stamp mill. The ores milled $11 in gold per ton. The Ontario Gold Mining & Milling Co. operated the Sakoose mine, which it purchased early in the year, and made shipments from it to the 20-stamp mill at Keewatin, which has a capacity of 50 tons per day. There was a stampede of prospectors to the Sturgeon Lake country during the summer. The Belmont gold mine made regular shipments of bullion, and in October resumed work

on the new dam and power plant which will supply the mine with compressed air as power. The British-Ontario Gold Co., Ltd., organized in London during the latter part of the year with a capitalization of £300,000, has a 99-year lease of the Alice A. mine under an agreement to produce 200 tons of ore per day. The Canadian Goldfields made regular shipments of gold and arsenious oxide during the year.

Mexico.—The mining and metallurgical industries of Mexico are well summarized by Dr. Joseph Struthers in the *Engineering and Mining Journal,* October 26, 1901, and a detailed description of mining in most of the States appears in the special issue of that paper of November 30, 1901, which contains a full record of the visit to that country of the American Institute of Mining Engineers. Many individual districts have also been described in the papers of the Institute which were read at the meeting in Mexico in November, 1901. The production of gold in Mexico for 1901 amounted to 499,725 oz. valued at $10,329,316, as compared with 455,204 oz. valued at $9,409,063 in 1900. The output of silver for 1901 amounted to 55,150,624 oz. equivalent to $32,511,293, as compared with 55,804,420 oz. ($34,269,494) in 1900. There are 11 mints in Mexico which receive gold and silver for coinage. The charge on silver is 4·41% and on gold 4·51% of their respective values, the payment of Government dues or taxes being accepted in any coins in legal circulation. Heavy exportation of silver coins from Mexico to the Orient caused a stringency in the money market during June and July, 1901, which was relieved by the importation of the fine silver from the San Francisco mint. Mexico has the right of way in supplying countries in the far East with silver coinage, which is there accepted as current exchange. The taxes on gold and silver ore are as follows: State and Federal tax, 2·6%; mintage tax, 4·5%; total, 7·1%, based on the gross assay value, to which must be added a stamp tax of 0·6% of the net value. Comparing the net return on a lead-silver-gold ore to the Mexican miner and to the miner of the United States, the latter receives about double that of the former. The mines of Mexico, however, are far less dependent on the market price of silver than those in the United States.

Chihuahua.—The smelting plants of the Chihuahua Mining Co. and the Sabinal Mining & Smelting Co. were shut down during 1901 and the ores are sold to the American Smelting & Refining Co., as are also the ores of the Candelaria Mining Co., at Ciudad Juarez. The smelting plant of this last-named company consists of three water-jacketed lead furnaces, one reverberatory roasting furnace, and two English cupelling furnaces. The ores are now shipped to El Paso, Texas, in bond for treatment. Sodium hyposulphite leaching of silver ores is practiced largely in Parral, where the Parral Mining Co. has a 100-ton plant. The crushed ore is roasted with salt at a cost of $2 per ton of roasted ore, and is concentrated before leaching to avoid difficulty in handling the slimes. A double hearth reverberatory furnace is used for roasting in preference to revolving cylinders on account of the large amount of zinc present in the ores, and supplementary cooling hearths are used to effect a secondary chlorination. At Santa Barbara there are three mills with a combined output of 450 tons, and a new installation of 350-ton capacity is being erected; in addition there are six private

mills in continuous operation, and a smelting plant is proposed to handle the daily production of 330 tons of ore which is shipped from the district. Among the large operators aside from the famous Batopilas mines, are the Hidalgo Mining Co., operating six mines and two mills with an output of 4,000 tons per month, and the Parral Mines Co., Ltd., operating a 400-ton concentrator. The Guggenheim Exploration Co. has a 100-ton mill in operation, and a 400-ton mill under construction. The Parral mining district is a large silver producer, and that the days of bonanzas is not past is proved by the recent strike by a poor peon of a large body of rich silver ore at a moderate depth in the Pamilla mine. The district of Santa Barbara yields gold in excess of silver.

Coahuila.—New smelters are being built which will treat the lead ores from the Sierra Mojada district. Formerly when no duties were collected these ores were hauled by teams to Escalon, and thence shipped to El Paso, Tex., or Argentine, Kan., but to-day as a result of the duties imposed in 1889 and 1896, a large part of the lead ores is treated in Mexico at the smelting works which have been established with American capital. That portion which is shipped to the United States is smelted in bond, and the resultant product sold outside of the country.

Durango.—The Duscubridora copper mine, in Durango, was purchased toward the end of the year for $2,000,000 by an American syndicate which is also heavily interested in the Mexican Central Railroad. A spur line is to be built from Conejos to Pelayo, a distance of 36 miles, to connect the river with the main line. New smelters were erected and operations on a thoroughly modern basis were inaugurated. Among the more important gold mining companies that have been organized during the year are The Mexican Mining & Smelting Co., capitalized at $10,000,0000 to operate in Durango. This company will erect a smelter at Monterey. The San Fernando mines in the northwestern portion of the State are operated by six turbines, producing 600 H.P. from the Humaya river. The mill equipment comprises a Blake crusher, stamp-mill, reverberatory roasting furnace, hydraulic classifiers, Wilfley concentrators, and canvas tables for the slimes. The smelting plant of the Compañia Minera de Peñoles, near Mapimi, consists of 10 specially constructed water-jacketed furnaces 36×100 in. section at the tuyeres. The hearth slopes to the front, and a separate bullion tap is provided at the side and 6 in. below the level of the slag and matte tap. This construction is made necessary by the strongly basic ores and the large amount of speiss produced.

Guanajuato.—The total production of gold and silver from the famous Veta Madre vein, including the Cardones district and La Luz mine, is estimated at a value of $1,500,000,000 Mexican. The shafts of the Millado and Rayon mines were first opened in 1588. The patio process, which is in general use in the vicinity, extracts 90% of the silver, 30 to 35% of the gold, and the extraction occupies from three to six weeks' time. It is now giving way to modern methods of milling and stamping.

Hidalgo.—The principal mining companies at present established in Pachuca, are the Real del Monte and Pachucha Mining Co. (the largest one on account of the number of mines in operation and its important management), the Santa

Gertrudis, Maravillas and San Rafael mining companies. Pachuca is pre-eminent among Mexican mining districts because of the variety and amount of machinery, drainage plants, milling plants and its recently inaugurated electric power plants. Its drifts, excavations and cuts represent not less than 300 km. in length. According to a rough calculation, Pachuca since its first discovery has produced not less than 3,500,000 kg. of silver.

Nuevo Leon.—The equipment of the Compañia Minera Fundora y Afinadora, at Monterey, consists of 8 steel water-jacketed blast furnaces each 42×120 in. section at the tuyeres, and 12 ft. 2 in. to feed floor; a Pearce turret roasting furnace, two reverberatory roasting furnaces, a liquation furnace, a 40-ton Parkes-process lead refinery and a Moebius electrolytic plant for parting gold and silver bullion.

Sonora.—To the natives of the famous La Cienega dry placers of Sonora is due the introduction to American use of the gold-pan, rocker, and other primitive placer utensils. These famous placers have been desultorily worked for more than 300 years. A recent examination and sampling of these fields yielded results averaging $1·84 gold per cu. yd., and large tracts assayed more than $3 gold for the same quantity. The Calera Gold Mining Co., capitalized at $750,000, has recently been organized to operate in the Magdalena district. The purchasers of the Mulatos gold concession have expended $150,000 in improvements at the mines and in the erection of a 125-ton stamp mill and a 250-ton cyanide plant. The El Paso-Sonora Mining Co. has been incorporated with a capitalization of $450,000 to operate gold and silver mines in the Moctezuma mineral belt. The Big Mountain Mining Co., with a capitalization of $5,000,000 has been organized to operate the historic Las Planchas de Plata mines.

CENTRAL AMERICA.—*Costa Rica.*—The exports of gold and silver from Costa Rica during 1901 amounted in value to $232,896. The Abengarez Gold Fields, Ltd., operated the Tres Amigos and Tres Hermanos mines during 1901, the reported production being from $8,000 to $10,000 per month. Arrangements were perfected by the company for increasing the original equipment of 10 to 40 stamps. The ore is said to carry from $5 to $200 in gold and silver, of which 90% is extracted. The Union mine, near Miramar, was idle during the greater part of the year owing to a serious fall that necessitated the opening of new tunnels at lower levels. Stamp milling with amalgamation and subsequent chlorination of the tailings is used at this mine; the ore body averages about $8 in gold, but is said to be extensive. The mine in the Ciruelitas district owned by the Bella Vista Mining & Milling Co. was taken over by the Thayer Mining & Milling Co., and operations were commenced with 40 stamps. Among the other events of the year were the consolidation of the Sacra Familia, Los Castros, and Aguacate mines under the title of the Aguacate Gold Mining Co., capitalized at $5,000,000, and the resumption of operations in the Porvenir mine by the Rio Grande Gold Mining Co.

Honduras.—The production of gold and silver for Honduras for the fiscal year ending June 30, 1901, amounted to £10,987 and £114,964, respectively. An increase over the previous fiscal year of £1,985 for gold, and £50,830 for silver. The annual report of the New York & Honduras Rosario Gold Mining Co. for

the fiscal year ending November 30, 1901, says that dividends amounting to $300,000 (20% on the capital stock of the company) have been paid, which makes the total dividends to date $1,695,000. The high-grade ore in sight in the mines is estimated at 33,500 tons. The development of the mining industry of this country has been very largely restricted to points easily accessible from the coast, due to the lack of railway facilities, which in great measure resulted from international controversy over the title to the railway concession financed in England some years ago. Aside from the well-established Rosario Mining Co., which produced practically the entire export of bar silver in 1901, other companies have recently met with some success, notably the Aramecina Gold & Silver Mining Co., Ltd., of London, which has found very good ore deposits and exported gold in considerable quantity. The mine is situated near the Pacific coast and the San Salvador frontier. Not far from it the El Transcito mine produces large quantities of low-grade gold ores, which are treated by the cyanide process. E. N. Burke, of Puerto Cortez, Honduras, controls the largest placers in Olancho, and on April 9, 1900, a contract with the Government was closed for Pennsylvania capitalists to establish navigation on the Ulúa and Comayagua rivers, and to build a wagon road from the Comayagua river to the Olancho gold fields, to be followed in 1901 by an electric railway to open communication with the mining districts.

Salvador.—The Butter's Salvador Mining Co., recently organized with a capitalization of £150,000 is continuing development work in its gold and silver mines of the Republic.

Nicaragua.—The occurrence of gold in parts of Nicaragua was recorded as far back as the 17th century, but it is only recently that there has been any systematic prospecting for and development of payable deposits. The auriferous region is situated some 200 miles from the Caribbean sea coast on the headwaters of the Principulca, Wanks, Was-Puk, Piz-Piz, Tunky and Wawa rivers. The geological formations of the region, according to J. D. Lowry (*Mines and Minerals,* February, 1902) include limestones of Carboniferous age, sandstones, shales and igneous dikes. Quartz veins varying from a few inches to several feet in width are found along the contact of the intrusive rocks and the shales and some of them are now being exploited. From the Constancia mine which is located on a vein 80 ft. in width carrying $8 to $10 in gold per ton, about $150,000 has been taken out in the last four years. The milling equipment of this mine consists of two arrastras. Modern stamp mills have been erected at the Bonanza and Sempre Vivre mines and more will be set up in the near future. The placer deposits are limited in extent, but they sometimes hold rich pockets; a record of 200 oz. of gold has been made by a single rocker working one day. On the whole the conditions for conducting successful mining operations are fairly good; the Nicaraguan mining laws are liberal, labor is plentiful, and the climate, while humid, is not unhealthy. The country however is not supplied with adequate transportation facilities, and commodities of all kinds in the interior consequently bring high prices. Cuicuina, on the Principulca river, and Cuicuinita and Salto Grande are the principal mining towns. The exports of Nicaragua in 1900 included $310,000 in gold bullion and $400,000 of gold ore.

SOUTH AMERICA.—*Bolivia.*—The most prominent gold mining companies of Bolivia are the Cheiquiaguillo and the Caiconi companies of La Paz, and the North American Co., of the Province of Cerado. There are nine other companies, of which five are English, and four French, at Tipuani. The Tuanani mines are said to yield 4·82 oz. gold per ton. From official calculations based on the valuations of travelers such as A. von Humboldt, it is stated the mines of Bolivia have produced from 1540 to 1750, $150,000,000 of gold. The second half of the 18th century added $25,000,000 to this. It is estimated that the silver production of Bolivia from 1545 to 1865 amounted to $1,500,000; in 1895 to $13,500,000, and in 1899 to $6,406,712 only. The diminished output is explained by the depreciated price of silver. The Pulacayo mine owned by the Huanchaca Co. was worked during 1901 under lease, by the American Smelting & Refining Co., the ores being shipped to the company's plant near Antofagasta, Chile, where they were smelted into base lead bullion, or, with copper ore into copper matte.

Brazil.—The State of Minas Geraes produces nearly all of the gold accredited to Brazil; alluvial deposits in other parts of the country, particularly on the border of French Guiana yield the remainder of the output. Most prominent among the mines of Minas Geraes are the Morro Velho (St. John del Rey), Passagem (Ouro Preto), Vieira, and Santa Guiteria, all located within the bounds of a small district. During the half year ending August 31, 1901, the Morro Velho mines produced 59,781 oz. gold bullion, equal to 45,309 fine oz. gold valued at $644,754. The quantity of ore crushed was 77,556 tons of an average yield of $8·44 per ton. The total costs amounted to $478,273 while the net proceeds of the half year's operations were $182,043. This mine has had an eventful history, extending over a period of more than a century, and has been worked by the present company since 1837. The lode which dips at an angle of 45° measures about 600 ft. in length by 45 ft. in width. The mining methods and equipment are modern and well adapted to meet the unusual conditions encountered. Great care has to be exercised in supporting the walls of the mine as disastrous falls have occurred resulting in the entire destruction of the workings and temporary abandonment of the mine. The system of overhead stoping and filling in beneath now used, is successful. The Ouro Preto Gold Mines of Brazil report an output during the year ending June 30, 1901, of 28,581 oz. gold, from which £87,037 was realized. The total expenses in Brazil and London were £82,715, leaving a balance, after including receipts from sale of arsenic and from rents, etc., of £5,107. Additions to the holdings of the company were made with the object of securing the mining rights for the deep levels to be opened in the future. Successful experiments were also carried out to adapt the cyanide process for treatment of the mill tailings. One of the drawbacks to the mining industry of Brazil is the continual fluctuations in the value of the currency which react directly upon the costs of labor, transportation and other items of expense.

Chile.—(By W. E. Mathewson.)—Very little silver ore was mined in Chile during 1901, the old bonanzas having been worked out and no new ones discovered. A small amalgamation plant in Iquique operated on ores from the immediate vicinity. The Fundicion Templeman at Antofagasta shipped a few thousand

ounces of bar silver smelted from native ores. The silver produced in copper mattes and base bullion at the Playa Blanca plant was imported from the great Pulacayo mine of the Huanchaca Co., of Bolivia. The Playa Blanca plant consists of 100 stamps, a blast furnace, and nine small cupelling blast furnaces. This plant was purchased by M. Guggenheim's Sons, of New York, in connection with a contract for the output of the Pulacayo mine of the Huanchaca Co., of Bolivia, on lease, the idea being to smelt the lower grade Pulacayo ore with lead furnished by the same mine, and ship the base bullion and high-grade ore to the Guggenheim plant at Perth Amboy, N. J. The company began operations in October, 1899, and continued until December, 1901, when the plant was finally closed down with the exception of a small sampling and shipping agency at Antofagasta. While the first six months of operation were successful financially, the tenor of the lead in the Pulacayo ore deteriorated from 12 to 2%, and sources of lead supply were sought, at first from old Spanish slags from Oruro, Bolivia, later in lead concentrates from Australia and British Columbia. These importations were found to be too expensive to smelt, and early in 1901 the silver ores were matted with the local copper ores, which contained about one-third of the copper in the form of Atacamite, the volatile oxychloride. These ores proved very undesirable for smelting on account of the volatile copper compounds which carried off large quantities of silver as well as copper in the furnace gases. It did not seem wise to build a condensing plant for the fumes under the terms of the lease, and the plant was closed, the ores being shipped to the company's plants in the United States.

Colombia.—(By P. N. Ospina.)—There is little to report regarding the progress of the mining industry in the State of Colombia during 1901, except that the civil war kept up its work of ruin and demoralization. The principal mines in Colombia are worked for gold and silver, chiefly the former. Ninety per cent. of the actual production of the country comes from the Department of Antioquia, the most central of the nine departments of the Republic. The value of the bullion exported last year is estimated at about $3,600,000. There are no statistics regarding ore exports from mines situated less than 20 miles distant from the Magdalena river, which is the principal waterway, but it must have been between 3,000 and 4,000 tons. The ore exported is mainly silver ore, which is shipped chiefly to England and Germany. Notwithstanding the civil war, mining in the interior of the country has been conducted with success. The rate of exchange in the interior ($1 in gold being worth from $30 to $45 in paper currency) has permitted the working of mines that would not pay formerly. Prospecting however has been greatly hampered by the difficulties and dangers incident to the war. Foreigners are usually respected and hospitably treated in Colombia, and have nothing to fear during periods of revolutionary agitation, provided they do not mingle in politics. For this reason mines and camps belonging to foreigners are usually left unmolested. There are two English companies operating in Colombia with most encouraging results, and there is also one French company. American capital is represented by a number of mining camps, generally located on small concessions, and apparently without much means. One of the most interesting mining events of recent years has been the

settlement of the old legal suit about the ownership of the Cruces de Caceres gold and coal fields, probably the most valuable concession of its kind in Colombia. The property is located in the north of Antioquia and is bordered by two rivers, the Nechi and the Cauca, both of which are navigable by steamboats.

Ecuador.—The mines in the Zaruma district, Province of Del Oro, are still being successfully worked by the South American Co., of New York. The output of gold for Ecuador for 1901 is reliably estimated at from $250,000 to $275,000, against $200,000 for 1900. A detailed account of the mining industry in Ecuador will be found in THE MINERAL INDUSTRY, Volume IX.

Guiana.—The total production of gold in British Guiana during 1901 was 102,258 crude oz. (about 900 fine), as compared with 113,749 crude oz. in 1900, showing a decrease of 11,491 oz., or 10·1% from the production in 1900.
The new 20-stamp mill (the first erected in the country) for the Concession Gros Co., of Dutch Guiana, was completed late in the year. The ores are sedimentary, composed of quartz streaks or conglomerates, in clay and kaolin formation. The deposits are covered with vegetable matter and average some 18 in. in depth. One of the deposits of this concession is 36 in. in depth and assays over $100 per ton; the average of the whole is, however, but $18 per ton. Gold is well distributed throughout the country, but the climate is very unhealthy, and a number of failures have been made through the erection of recovery plants not suited to the deposits. Rich placer gold diggings in the Inini river district of French Guiana are attracting many prospectors to that locality. During October and November of 1901 over 29,167 crude oz. of gold were brought down to Cayenne, and other lots were expected to follow before the end of the year.

Peru.—A Hamburg company, capitalized at $357,000, has been registered to acquire the property and rights of the Compania Aurifera del Inambari, which has operated to some extent at Poto, in the Sandra district. The largest part of the Cerro de Pasco district silver output, which amounts to 643,000 oz. annually, is obtained by the sodium hyposulphite treatment of the old residues, which contain from 3 to 5 parts of silver per 10,000. The interest in copper in this district has resulted in neglect of the silver mines. The latter are either in bad condition or inundated with water, and at the low prices for silver there is not much inducement to resume work. In January, 1901, a company was formed at Lima, Peru, to drain the inundated mines at Cerro de Pasco. The company is capitalized at 500,000 soles ($243,500). A United States consular report notes the organization of La Sociedad Nacional de Mineria, with headquarters at Lima, Peru, and request is made that a full line of catalogues be sent to the society, to enable them to make recommendations to the Government or other purchasers of machinery of material deemed suitable to Peruvian conditions.

Uruguay.—The output of gold in 1900 from the quartz mines of Cunapiru, San Gregorio, and Santa Ernestina amounted to 2,315 oz., valued at $33,345.

Venezuela.—Gold mining during the past two years according to statistics reported by the Custom House has retrograded slightly, yet there is reason to believe that owing to a temporary high tax on the export of gold a large proportion has been taken out of the country by illegitimate means. The Gold Fields of Venezuela, Ltd., a British enterprise, has successfully introduced the cyanide

treatment of mill tailings at its mines in the Yuyuari district, and it is expected that the application of this process will allow the treatment of extensive deposits of low-grade quartz which formerly, owing to the excessive cost of labor and the loss of gold in the mill tailings, could not be worked with profit.

EUROPE.—*Norway.*—The principal silver mines are those belonging to the Government, located at Kongsberg, which have been worked since 1624 with varying success. About 5 tons of silver is the annual output of these mines. Of late a new and very promising lead has been struck. Other silver mines are located at Trollerud, 10 km. north from Kongsberg, at Eidsvold and at Svenningsdal, in Vefsen, Nordland. Silver is otherwise found in many different places, but not in paying quantities. The exports of silver ore in 1899 were valued at about $1,000.

Russia.—(By C. W. Purington).—The mining conditions of Russia so far as reflected in the statistics of production showed some improvement last year. The output in 1901, based on the receipts of the St. Petersburg mint but making a necessary allowance for gold finding outlet by other channels, was 1,253,592 oz. ($25,911,744), against 1,072,434 oz. ($22,167,201) in the previous year. Quartz mining and milling in Siberia and eastern Russian has made little progress. In the two districts of Ekaterinburg and Kochkar, of the Ural region, there are at present about 150 stamps dropping and some half dozen mills of the Chilean type in operation. At Kochkar several small cyanide plants for treating tailings have been erected. On the river Reft, about 100 miles N.E. of the city of Ekaterinburg, there is an auriferous slate deposit, from which about $350 in gold is extracted daily. The ore is treated in a 10-ton Chilean mill. The Chernyladeff Co. owns a similar deposit in the same district which it is working with a 10-stamp mill. The mills in the Ural district are of small capacity and the stamps do not average over 600 lb. each. They are built by Thomas Yates, of Ekaterinburg. Recent operations in the Marinsk district of western Siberia have been very successful, but no complete data as to results are available. Rich finds of gold quartz were made in the summer of 1900, and a 10-stamp mill has been in operation for about one year. The results for 1901 were said to be 6 Russian pounds of gold per day, the Russian pound being about nine-tenths of the avoirdupois pound. The fineness of the gold is not known. In the Achinsk district Mr. C. I. Ivanitsky installed a Krupp 20-stamp mill during the spring of 1900. Ten stamps have been in operation for the better part of two years, the first mill having been partially destroyed by fire. The Fyedorovsky mine, near which the mill is located, has long been operated as a placer, and as such, is practically exhausted. The operations here have yielded about 5 Russian pounds of gold per day from 18 tons of ore, the gold having a fineness of 850. The mill is operated by electric power generated by water. The valley of the Sorela Ooyoos river, in the Achinsk district, about 100 miles south of the Trans-Siberian railway, has recently been the seat of extraordinarily rich quartz finds. The ore is free milling and occurs as a solid quartz reef, averaging 12 ft. in width. The ore thus far encountered runs about $15 per ton. There are also other large reefs in the same valley, but as yet they have not been exploited. On the Onon river, in East Siberia, S.E. of the Irkutsk, large deposits of low-

grade ore are worked by different Russian companies, the largest property being owned by the Messrs. Sabachnikoff. The mills in operation in this district are of small capacity and poorly constructed. Near Urga, in Mongolia, an American company has installed a 10-stamp mill which was operated during last year. Little has been done so far toward developing the quartz mining industry in Siberia, especially in dealing with refractory ores. All of the districts mentioned above produce gold from free milling ores only. In the Urals a few reduction plants for treating refractory gold ores, have been erected.

Spain.—There is some prospect that gold mining will be resumed on an extensive scale in this country after a long period of decline during which the output has dwindled to a few hundred ounces a year. In the district of Corunna, alluvial concessions have been taken up by three foreign companies, and a quartz deposit is to be exploited by the Sagasta Gold Mines, Ltd., of Glasgow. Several mining concessions covering properties in the Province of Leon have also been granted. El Oro Español, capitalized at 2,000,000 pesetas, has started operations on the auriferous mining properties on the Duerna river and many new mining concessions have been registered to work auriferous properties in the Leon province. The principal alluvial concessions in the Corunna districts have been taken up by the Société Anonyme, of Brussels, with a capital of $300,000; the Valdeorras Gold Mining Co., and the Valdeorras Alluvial Gold Mining Co., of London. The gravel or sand contains 1 oz. gold per cu.m., which is reported to be extractable at a working cost of 10c. There is a group of quartz mines 30 miles from Corunna operated by the Sagasta Gold Mines, Ltd., of Glasgow; the lode averages 18 dwt. gold to the ton, and a cyanide plant has been erected. As a large part of the gold is contained in pyrites, a concentration plant is contemplated. The mines belonging to the company are the Sagasta, Alfonso, Maria Christina, Linares Rivas, and the Pretoria.

United Kingdom.—The report of the St. David's Gold & Copper Mines, Ltd., for 1901, showed an output of gold bullion and concentrates valued at £20,254, equivalent to 4,772 fine oz., which was obtained from 15,517 tons of ore. The net profits of the year's operations were £6,563. An additional 20-stamp battery was erected which, with the improvements to the concentrating plant, will doubtless lead to an increased production in 1902. Some gold was also obtained at West Seton in the Camborne district by a company which treated old mine dumps. The total output of gold in the United Kingdom during 1900 was $253,747.

AFRICA.—*Abyssinia.*—There is much discrepancy in the estimates of different authorities as to gold output of Abyssinia. According to the Diplomatic and Consular Reports of the United Kingdom, the annual export from Addis Abbaba and Harrar is about $650,000. This amount is probably too high. French authorities state that the annual sales by natives are about 10,000 oz., and upon this basis the total product may be estimated at 20,000 oz. as a maximum limit.

Egypt.—Recent exploration in the desert region between the Nile and the Red Sea has shown the existence of ancient gold mines that were once worked on an extensive scale. The Egyptian Mines Exploration Co. during 1901 explored the ancient gold mines in the district between the Nile river and the Red

Sea. The Egyptian Development Syndicate during the latter part of the year began operations on the peninsula of Sinai. These companies are operating on large prospecting areas granted them for a time by the Egyptian government, with the right to locate and hold on certain specified terms any mines discovered therein. Early in 1902 the Egypt & Soudan Mining Syndicate will begin operations, and probably others will get permits. Quartz veins discovered by the Egyptian Mines Exploration Co. at Um Rus on the Red Sea about 240 miles south of Suez appear to be of good value, contain but little pyrites, and have been worked in ancient times to a considerable depth. A shaft to a depth of 130 ft. has not yet reached the bottom of the old workings which have exposed a vein for a length of 700 ft., varying from 1 to 3 ft. in width.

Gold Coast.—There was less interest manifested on the part of the British public in the flotation of companies to operate on the Gold Coast, and the market quotations for shares of the established companies was on a lower level than that prevailing in 1900. The reaction was due in part to the unfavorable reports of engineers commissioned to investigate the properties and in part to the fact that the results obtained by companies actually engaged in development work fell short of expectations. The general consensus of opinion among mining men familiar with the field indicates that there is a basis on which to build a legitimate and successful mining industry, although the deposits are by no means equal in extent and regularity to the formation of the Transvaal, with which they have been compared. The development of the country must necessarily be slow, owing to the adverse conditions of climate, transportation and labor, which probably exceed in difficulties those found in any other district of the world where lode mining has been carried on successfully. It is stated that under the present conditions no profit can be made from free milling ore carrying less than 1 oz. gold per ton. The Wassau district, containing the banket reef formation, promises to develop some productive mines in the near future. The district is now in communication with the Coast by the Secondi-Tarkwa railroad, and development work has been actively prosecuted at several concessions. At the Adjak-Bippo mine, operated by the Wassau Mining Co., Ltd., the reef was found at a depth of 770 ft., having a thickness of 3·5 ft., and assaying 22 dwt. per ton. In the Prestea district the mines are located on quartz veins, some of which are extensive and carry good values. Operations have been conducted here intermittently for the last 15 years, but on the whole they have been unprofitable. The Prestea Appantoo mine was engaged last year in sinking a main shaft. The company has two mills of 30 stamps and has already crushed about 4,000 tons of ore. At the Broomassie mine, which has been worked for 10 years, there are over 1,000 ft. of tunnels and a 20-stamp mill has been installed. The exports of gold from the Gold Coast in 1900 were 12,774 oz., valued at £51,062; as compared with 14,249 oz. (£51,300) in 1899.

Ivory Coast.—The principal events of the year were the granting of a large number of mining concessions and of a banking commission to the Banque de l'Afrique which will operate in this country. Plans were developed also for the construction of a railway 120 miles in length between the Baudama and Comoe rivers passing through the mining district. The gold deposits, according to

J. N. Griffiths, occur as banket reefs in regular conglomerate beds, while the geological formations of the region include sandstone, shale, schist and quartzite, broken through in places by dikes. There are also alluvial deposits that could be worked advantageously with steam dredges.

Madagascar.—The output of gold in 1900, as estimated from statistics of exports, was $608,000 against $228,622 in 1899. Nearly one-half of the output in 1900 came from the new gold fields in the Ampassary country. No quartz ores have been worked as yet, although they have been discovered in several localities, the entire product being washed from alluvial deposits, mostly in the native wooden pan. Discoveries of placers have been made recently in the eastern part of the island near the port of Manangary, which, while not as rich as those of Ampassary, are said to be more extensive.

Portuguese East Africa.—Discoveries of gold in the Sasa country were reported during the year, but they have not been confirmed by credible authority. The locality is in the Yuanatsi district near the Transvaal border.

Rhodesia.—The production of gold in 1901 was 148,753 fine oz., valued at $3,074,730, an increase of 69,399 oz. or $1,434,479 over the output of the preceding year. There has been a steady development of the gold mining industry since the native rebellion was quelled in 1897, although the Boer war and the insufficient supply of skilled labor have been serious drawbacks to progress. Efforts were made last year to partially supplant the Kaffirs, who are unsatisfactory workmen, with natives imported from other parts of the country and with Arabs, but the results did not justify a continuation of the experiment. It is possible that the only solution of the question will be found in the introduction of laborers from other British Colonies or from China. With the development of the coal fields now under way, a supply of good fuel will be made available, much to the benefit of the mines, which at present are compelled to rely upon native wood. A company known as the Ayrshire Gold Mine & Lomagunda Railway Co., Ltd., has been formed to work the Ayrshire mine in Mashonaland and to construct a railway from Salisbury to the mine. The share capital is £400,000, of which £100,000 will be held in reserve. A further working capital of £250,000 is to be raised by the issuance of bonds bearing interest at 5·5% guaranteed by the British South Africa Co. and the Rhodesia Exploration & Development Co., Ltd.

Transvaal.—Although the Rand district has remained in possession of the British army since May, 1900, little progress has been made in re-opening the mines and starting the mills. A few companies resumed operations on a small scale in May, 1901, and the number was gradually increased until near the close of the year there were 11 mines partially operated, with a total of about 600 stamps, as compared with an average of 5,762 stamps operative during 1899. The output for 1901 was 238,991 oz., valued at $4,939,944, against 348,760 oz. ($7,208,869) in 1900 and 3,529,826 oz. ($72,961,501) in 1899. Dividends paid during 1901 amounted to £415,812, which corresponds to 20s. 2d. per ton milled. It is probable that the output will steadily increase from now on until all of the mines are again in full operation when the productive rate will probably be above $100,000,000 per year. During the enforcement of martial law

by the South African Republic, the Rand district was completely under its control. Twelve of the larger mines were operated and gold to the value of about $10,000,000 extracted which was appropriated by the Government. The direct losses sustained by the companies during this period, though considerable, were less than had been expected, as very little wilful damage was done by the Boers. The principal item was the cost of maintenance and pumping, amounting to nearly $10,000,000, while the total may be placed at about twice that figure. These estimates must be largely increased to include the entire losses sustained during the long period of inactivity and the re-opening of the mines. One of the chief difficulties encountered since the resumption of operations has been the inadequate supply of native labor. The Kaffir workmen who were dispersed during the war have not returned in sufficient numbers, and under the present conditions, which do not permit the former freedom in dealing with the natives, there is no immediate remedy available. During the past four years the scale of wages for mine laborers has been frequently reduced by wide margins, and the natives, especially the more competent class, do not take kindly to this treatment. A proposal was made by Mr. Cecil Rhodes to import Chinese and Indian coolies for the Chartered Company's mines, but so much opposition developed that the plan had to be abandoned; it is probable that such a proposal would be received in a similar spirit on the Rand. An event having an important bearing on the future development of the district was the striking of the gold reef series in the Turf Club bore-hole south of Johannesburg at a depth of almost 5,000 ft. On the main reef the ore body was proved through 45 in. with an assay value of 8·44 dwt. The richest portion being 25 dwt. over a section of 10 in. The south reef showed a thickness of 43 in. assaying 10·6 dwt. with a maximum of 32 dwt. over 9 in. The results are highly satisfactory, indicating the extent of the ore bodies over a large area. To what depth mining can be carried on in the Transvaal is a problem of great importance, upon which directly depends the life of the mines. According to Mr. John Hays Hammond there are no factors operating against mining to a depth of 8,000 ft. vertically, except the additional cost of haulage, pumping and ventilation, which will not be prohibitive. As the increment of temperature is exceptionally small, amounting to 1°F. for each 200 ft. in depth, no difficulty is expected from this source. Another prominent engineer, basing his conclusions upon the temperature factor, is of the opinion that the reefs can be worked down to 12,000 ft. vertically. While there is no certainty what the ultimate limit will be, it is evident that mining can be continued to much lower depths than have been attained thus far in any mining field of the world. As to the output of the district, it has been estimated that the reefs will yield about $50,000,000 for every mile on the strike and 1,000 ft. on the dip. This estimate is regarded as conservative by Mr. Hammond, who places the available gold in the ore lying within the practicable mining depth of 6,000 ft. at about $3,000,000,000. This figure must be increased by $1,000,000,000, according to Messrs. Hatch and Chalmers, to include the gold product of the east and west portions of the Rand. As to the duration of mining on the Rand, Mr. Hammond has expressed the following view: . . . "the tendency is to exploit the auriferous areas as rapidly as possible and engineering

methods are all adopted with that end in view. If the exploitation of the deeper levels is not delayed pending the proving of the ground lying above, but is carried on concurrently with the exploitations of the higher horizons of the reefs, the industrial life of the district will, of course, be correspondingly shortened. The working of lower grade ores, made possible by improved economic conditions or other circumstances, would tend to increased longevity of the industry. But were I called upon to express an opinion, I would estimate the future duration of profitable operations on a large scale in the district, at less rather than more than 25 years." The following data give the relative working costs for some of the leading Transvaal mines in 1898: White labor, 31·22%; native labor (including food), 29·83%; explosives (dynamite, fuses, caps), 9·70%; coal, 9·07%; chemicals (cyanides, etc.), 3·22%; tools, steel, shoes, dies, etc., 3.29%; mining timbers, lumber, 4·05%; candles, lighting, 1·38%; sundries, 8·24%; total, 100%.

ASIA.—*Borneo.*—In British Borneo, which comprises the northerly portion of the island, the principal gold mining operations are conducted by the Borneo Co., Ltd., at Bau and Bidi. The company has two cyanide plants disposing of about 16,000 tons monthly and is contemplating the erection of a third plant. Chinese labor is largely employed and the mining costs are low. The exports of gold from this part of Borneo in 1900 were 19,873 fine oz. valued at $410,038. A review of the gold mining industry in Dutch Borneo will be found under Dutch East Indies.

China.—The unsettled condition of affairs in China incident to the native uprising against foreigners has greatly hampered mining operations, especially in the northern part of the country where the principal gold fields are located. The output in 1900, according to estimates based upon the most reliable authorities, was about $4,300,000. No information is available as to the production last year, but it may be safely assumed that the amount did not exceed $3,000,000 and probably fell short of this sum. The present outlook for the industry is more encouraging than for several years past; the policy of the Government in granting liberal mining concessions to foreigners should attract capital and offer a more permanent basis for mining enterprises than has been possible under the conditions that have prevailed heretofore. Auguste Mathez, in *Mines and Minerals,* April, 1901, gives a description of an exploration trip in northern China in June, 1900, covering a concession in the district Chai-luh about 100 miles north of Peking. The values of gold, silver and copper were mainly contained in white quartz; in one instance only was the vein filling felsitic. The deepest mine visited was 120 ft., a depth beyond which it was impossible to go with the primitive method of mining pursued on account of the water filling the vein. No powder was used for blasting, the rock being detached by the old Roman method of first heating the rock and then throwing cold water on it. Other mines were examined which showed free gold at the surface running into sulphurets a short distance below and in one instance the ore was of chalcopyrite, the vein measuring 18 in. in the deepest level and averaged 20% copper with 3·5 oz. gold and 10 oz. silver per ton; generally the gold values were much less than this and averaged from $2 to $20 per ton. The miners work in inde-

pendent sets, and it is quite common to find a number of pits strung along a vein with only a few feet of ground separating them. The ore is crushed in roller mills similar to a Chilean mill and the pulp shoveled onto an inclined board 4×2·5 ft. held at a slight inclination on the lap of the operator and washed by water thrown on by a boy. The concentrates were worked back with a small rake until of satisfactory condition and the product then panned by hand to extract the gold, the silver and copper contents being lost. A deposit on the borders of Manchuria was examined and while the veins were similar to those in the Chai-luh district, they were of very low grade. The placer mines at Pa-kau were examined also. The mining has been done in a very crude manner, the ground being worked out by innumerable pits to the bed rock, beginning at the top instead of at the bottom of the gulch. All of the excavated material was panned by hand, giving employment to thousands of people.

Dutch East Indies.—Some progress has been made in the exploration of the gold resources of Celebes, where several companies are operating under concessions from the Dutch Government, and the mining industry has gained a foothold in Borneo and Sumatra. According to S. J. Truscott, in a paper read before the Institute of Mining and Metallurgy, November, 1901, nearly 100 exploration companies have been formed during the last five years to operate in these fields. In Sumatra the Redjang Lebong mine situated some distance from the coast town of Bencoelen is the principal mining center. This mine was opened in 1898 upon a reef 1,000 ft. in length and 17 ft. in width. Since that time a 40-stamp battery and cyanide plant have been erected and work actively prosecuted. The ore is a close-grained amorphous silica carrying finely disseminated gold in the free state and also as auriferous silver in the proportion of one of gold to 10 of silver. Up to the end of 1900, with an average run of from 10 to 20 stamps the operating results were: ore crushed, 12,072 tons; fine gold produced, 11,308 oz.; fine silver produced, 73,493 oz. In addition there was an accumulation of 2,423 tons of slimes which it is estimated will yield 3,876 oz. gold and 24,230 oz. silver, increasing the total extraction to 25·1 dwt. gold and 8·1 oz. silver per ton, or 85 and 67% respectively of the assay values. The output in 1901 showed a large increase over previous years. About five miles west of this mine is located the Lebong Soelit deposit with an indicated length of 2,000 ft., a width of 8 ft. and an average tenor in gold of about 20 dwt. A tramway has been constructed from the mine to a river that is navigable for light-draft boats to the coast. In the central part of the island around Fort Kock and Soepajang there are also auriferous areas but no veins of value have thus far been discovered. Dutch Borneo contains three auriferous districts: in West Borneo around Sambas, in Central Borneo at the sources of the Kahajang and Kapuas rivers, and in the southeastern portion of the island. A large amount of exploiting work has been done in West Borneo recently with a view of locating the sources of the gold found in alluvial deposits. The results so far have not been very successful, as such veins as were encountered showed little persistency in depth. However, there are large areas of alluvial ground which may be made the basis of profitable exploitation. Central Borneo contains the Kahajang mine, located some 200 miles from the coast, near a stream of that name. A

20-stamp mill has been erected and ore is being taken from two quartz reefs, of which the larger is 3·5 ft. in width and carries 1 oz. gold and 12 oz. silver per ton, while the smaller is about 1 ft. in width and has an assay value of 5 oz. gold or more per ton. Trial crushings with amalgamation gave a recovery of 260 oz. bullion from 139 tons of ore. A third quartz reef 8 ft. in width and carrying about 0·5 oz. of gold occurs in the vicinity of the mine, and a fourth at a distance of about five miles has been prospected with good results. The country rock consists of granites and slates, both of which are traversed by the quartz reefs and by dikes of andesite. Gold is also obtained from alluvial washings in numerous localities. The deposits in southeastern Borneo consist of placers, but there are indications that gold occurs also in the igneous country rock. In Celebes the gold bearing area is confined to the northern part where are located the mining camps of Palehleh, Soemalata, Denerki Bay, Totok and Kotaboenon. At Palehleh, the Nederland Indische Gold Mining Co. is operating on a reef composed of quartz veins and stringers that carries free gold and sulphides. The average width of payable reef is about 6 ft. and the gold tenor varies from 6 dwt. to 4·5 oz. per ton. The poorer grade of ore is crushed in a 30-stamp battery and theh pulp passed over amalgamated plates which save 58% of the assay value and then over blanket tables where another 15% is recovered. After this the tailings are concentrated on Frue vanners, which effect a final saving of 11%. Ore of the richer grade is shipped at present to Europe, but the company is planning to erect a smelting plant at the mine for its treatment. Soemalata lies about 40 miles west of Palehleh on the coast. The ore consists almost entirely of sulphides and occurs in a vertical vein breaking through andesite. The coarse ore as it comes from the mine is hand-sorted and passed directly to the smelter bin, while the fines are run through rotary sieves and sized into three products, of which the two finer are jigged and the coarser hand-sorted. This treatment of the fines brings the tenor up to that of the coarse ore which is about 30 dwt. gold and 4 oz. silver per ton. The material containing 50% Fe., 30% S, and 1% Cu is smelted with coral and wood, resulting in a concentration of four of ore into one of matte. The matte is sold in Europe. At Totok the gold occurs in a free state in a quartz gangue. A 20-stamp battery has been set up, and a crushing of 400 tons with amalgamation alone returned 5 dwt. 8 gr. gold per ton. Trial crushings of ore occurring at Kotaboenon have been made which gave a recovery of 5·6 dwt. gold and 15·2 dwt. silver per ton. The mining areas of the Dutch East Indies are thinly populated and labor for the mines must be imported. Chinese and Javanese coolies are usually employed, the former giving better satisfaction. The right of exploration for minerals is granted to such persons or companies as are domiciled in Holland or its East Indian colonies upon application to the Government. This right holds for a term of three or five years on an area not exceeding 52,500 acres in extent, for which an annual rental of about 4c. an acre must be paid. If payable ore be discovered, the holder of the prospecting right, or "vergunnung," upon complying with the stipulations of the law as to domicile and financial responsibility, may receive a concession for exploitation. Concessions are granted for periods of 75 years, during which payments must be made to the

Government of 2·5% of the yearly output of mineral and of 40c. per acre of area conceded. The climate of the gold districts is tropical, but if proper precautions are taken it is not especially formidable.

French Asia.—This French colony is comprised of Cochin China, and the protectorates of Annam, Tonkin Cambodge, Laos, the mountainous region between Annam and Laos, and the territory of Kouang-Tchéon-Ouan. The total area of territory is estimated at 630,000 sq. km., and supports a population of 20,000,000. Gold appears to be distributed over much of the country both in quartz and alluvial deposits. The series of veins and alluvial deposits of Quang Nam in the province of Annam appear to be the most important, and have been worked on a comparatively large scale by the ancients. The mines at Bong Miû have been recently operated by the Société des Mines des Bong Miû, and a 30-ton mill has been installed which has given good results in gold recovery.

India.—The Colar field produced 504,348 crude oz. of gold in 1901, an increase of 9,318 oz. for the year. In addition there was a small output in Nizam's Territory, Burma, and Madras, which brought the total for India in that year up to 455,871 oz. ($9,422,855) as compared with 448,100 oz. ($9,262,226) in 1900. The largest mines are the Mysore and Champion Reef of the Colar field with an annual output of more than 150,000 oz. each, and the Ooregum, Nundydroog and Balaghat mines in the same district with a combined product approximating the same figure. The report of the Champion Reef Gold Mining Co. for the fiscal year ending September 30, 1901, shows an income from the sale of gold of £603,792 and a total income, after deducting royalty to the Government, of £576,329. The expenditures amounted to £242,817, leaving a net balance with the amount carried forward from the previous year of £335,451, out of which £334,359 in dividends were paid. The average yield of ore milled was 1 oz. 4 dwt. 11 gr. per ton, a falling off of about 6 dwt. per ton from the previous year's average. A new cyanide plant and mill were placed in operation which it is expected will maintain the output of the mines at a high rate, even if the tenor of the ore in gold should continue to be low. Discoveries of ore carrying good values were made in the deeper levels opened during the year. The Mysore Gold Mining Company, Ltd., during 1901 treated 127,070 tons of quartz, which yielded by amalgamation 147,354 oz. of gold. From the cyanide works and slags a further 17,227 oz. were obtained making the total extraction 164,581 oz. The sum of £641,977 was realized from sales of gold, yielding a net amount of £610,165, after deduction of royalties. The total net receipts were £614,167 and the expenses were £239,802, so that the net profit for the year's operations was £374,365. The sum of £376,911 was appropriated for dividends, leaving a balance of £1,410 to be carried forward to the account of the following year. The dividends were at the rate of 130% on the share capital of £265,000. The quantity of ore treated was 10,494 tons more than in the previous year, while the increased output of gold was 4,486 oz. From the cyanide works the amount of gold obtained was 2,988 oz. less than in 1900, so that the gain in the year's output was 1,448 oz. The total return of 164,581 ounces was a record for the mines. A large amount of development work was performed, and the estimates show that at the close of 1901 the ore

reserves were about 340,000, or practically a three years' supply for the mills. Successful negotiations were carried on with the Mysore Government for a renewal of the leases under which the company is working; according to the terms agreed upon, the Government is to receive a royalty of 5% of the value of the gold extracted and a payment of 2·5% on dividends distributed after March 22, 1910. The Nundydroog Co., Ltd., during 1901 produced 56,997 oz. gold from 52,030 tons of ore and 60,216 tons of tailings. The available profits of the year's operations were £105,193. In the same period the Ooregum Gold Mining Co., Ltd., recovered 86,918 oz. of gold, from which a profit of £157,472 was realized.

Japan.—The output of gold in 1900, according to official sources, was 2,130 kg., equivalent to 68,482 oz. or $1,415,523. The increase over the preceding year, which amounted to about $300,000, was due chiefly to the working of the new placer deposits in northern Jesso. Some gold was mined in Formosa in the vicinity of Kelung.

Korea.—The gold resources of this country are being rapidly developed under the direction of foreign companies who have received large concessions of gold-bearing territory from the Government. One of the most important concerns operating at present, the Oriental Consolidated Mining Co., of Woonsan, backed by American capital, is operating a grant of quartz and placer land. The company owns the mining rights in a district some 25 by 30 miles in extent which is said to be the richest known gold region in Korea. Two cyanide plants have been erected for treating the tailings from the stamps, of which there are two installations of 20 stamps and two of 40 stamps. The mining staff comprises about 70 foreigners as officials. The 3,000 native laborers are paid from 15 to 25c. per day, the highest wages ever paid in Korea. The British concessions extend over the Unsan district in the vicinity of the region occupied by the American company. At the Gwendoline mine development work was continued throughout the year on a quartz reef carrying pyrites and gold. A part of the mining equipment was set up and crushing will probably begin early in 1902. The mine is reached by 11 miles of roadway extending from Ko Hol on the Hoo Gin river, whence communication is had by water with Chinnampo. The company employs about 15 foreigners and 700 natives. Extensive coal beds have been discovered at Tensan, 10 miles north of the Gwendoline mine. A German syndicate was engaged in prospecting for gold at Tangokae, with 12 foreigners and 500 Koreans on its staff, and a new concession was granted to a French subject covering territory as yet undefined. Some work was done on the Japanese district south of Seoul, but the Russian concession has been but little explored. The exports of gold from Korea in 1900 were 3,633,050 yen, or about $1,816,525, against 2,933,382 yen ($1,466,691) in 1899.

Malay Peninsula.—The Australian Raub Gold Mining Co. has been operating mines in Pahang for some time, through its two subsidiary companies, the Punjom Gold Mining Co. and the Kechau Gold Mining Co. The parent company owns a 60-stamp Australian mill, which is equipped with electric power. It is reported that the ores range from 7 to 8 dwt. gold per ton on the average with occasional rich patches, and that the expenses of mining and milling are about 15s. per ton.

In Negri Sembilan the Chindras Co. is operating a property of 50 acres and erecting a 15-stamp mill. The Taong gold mine recently financed in London is reported to have an ore body averaging 9 ft. wide, and assaying from 4 to 30 dwt. of gold per ton. The Kedana Gold Mining Co. in Johore is developing a lode carrying arsenical pyrites and some 14 dwt. gold per long ton. Old alluvial workings are reported on the rivers Sungeis Tenoh, Ayer Terap, and Anak Kadana. The deposits of Johore are not more than 30 miles from navigation.

Philippine Islands.—The island of Mindanao has been for many years the seat of desultory mining for gold, but the output has been irregular and very limited in amount. In the Pigholugan region the deposits consist of quartz veins in a soft argillaceous slate with bedding planes inclined at a high angle from the horizontal. The veins range up to 4 in. in width and occur in three sets, two of which are vertical and cross each other nearly at right angles, while the third is conformable to the stratification of the slate. The natives in exploiting the deposits excavate deep trenches on the course of the main veins and then dig shallow shafts at the points of intersection which seem to contain the best gold values. According to J. Clayton Nichols, in a paper read before the American Institute of Mining Engineers, November 19, 1901, as much as $4,000 has been taken from a single hole, yet the deposits are unsuited for operation by large corporations on account of their small size. The region is several miles in extent, and nearly all of it is public domain. Another gold locality that has been exploited by the natives lies about 10 miles west of the port of Surigao. The gold is found in loose surface material which bears evidence of being disintegrated serpentine.

AUSTRALASIA.—The production of gold in Australasia during 1901 amounted to 3,724,996 fine oz., as compared with 3,569,844 fine oz. in 1900, an increase of 155,152 fine oz. Western Australia and New Zealand alone show increased yields of gold, the remaining States recording declines, principally due to the extended drought which greatly restricted mining operations. It is interesting to note that the Australian mining journals have departed from their former practice of reporting the gold yield in crude ounces, and now use fine ounces, which is in conformity with the world's standard for such statistics. The percentage of fine gold contained in the crude bullion obtained from the various Australasian mines differed so greatly in amount that a lengthy process of translation from crude to fine ounces is now avoided. The general success of the sulphide reduction processes for the gold telluride ores of the Kalgoorlie

PRODUCTION OF GOLD IN AUSTRALASIA.

States.	1900.		1901.	
	Fine Oz.	Value.	Fine Oz.	Value.
New South Wales	281,207	$5,812,539	216,874	$4,482,785
New Zealand	338,902	7,005,103	412,189	8,519,947
Queensland	676,029	13,973,736	576,920	11,924,986
South Australia	25,713	531,498	(a) 21,939	453,473
Tasmania	73,578	1,520,867	52,627	1,087,800
Victoria	760,142	15,712,140	743,467	15,367,463
Western Australia	1,414,273	29,233,035	1,700,980	35,159,357
Totals	3,569,844	$73,788,918	3,724,996	$76,995,660

(a) Including 18,028 oz. from the Northern Territory.

mining district, accounts in great measure for the increased gold yield of Australasia, and as these plants are being rapidly installed it may be safely predicted that the year 1902 will show a still greater gold production than that of 1901.

New South Wales.—The production of gold for the year 1901 was 216,874 oz., valued at $4,482,785, as against 281,207 fine oz., worth $5,812,539 during 1900. This decrease was due to the general drought and the business and financial depression, the first crippling operations of existing mines, and the second preventing the opening and development of new mines. In Wyalong a number of mining leases were consolidated, and a company is being organized to operate them which is to be capitalized at £130,000, of which £40,000 will be expended in sinking on the reef. The ore exposed in the Messrs. Neeld's mine, at Wyalong, is valued at £500,000 and the ore on the surface is estimated to contain £40,000 of gold; crushing operations continue to yield satisfactory returns. At the Baker's Creek mine, at Hillgrove, the last clean up returned the following: 750 tons of ore yielded 710·15 oz. of box gold, and 474·65 oz. of plate gold, a total of smelted gold of 1,175·8 oz. The Christmas Gift gold mine at Cullinga, 12 miles southeast of Cootamundra, returned from 2,500 tons of ore crushed last year, 1,627 oz. gold saved by amalgamation, and about 500 oz. recovered by smelting with copper ores or recovered from concentrates by cyaniding. The Dawn of Hope mine, on the same reef as the Christmas Gift, has opened and exposed a large body of low-grade ore, and the management is now sinking deeper in the hope of encountering shoots of richer ore. Several gold prospects of Cullinga yield 0·3 oz. per ton and the reefs are large, but capital is lacking to treat them on the large scale necessary with such a low return. The Burdett-Coutts mine, at Canowindra, which has been worked by different managements for the past 10 years without much profit to the stockholders, has a main shaft 500 ft. in depth, and a winze sunk from the 500-ft. level for another 100 ft. The 500-ft. level has been driven on the vein for a distance of 420 ft. without a break, and the value of the ore has never been less than 1 oz. gold per ton. In the Gundagai mining district a new auriferous section has been opened above the famous old Jackalass alluvial lead. Some miners, while tracing the source of alluvial gold, found a quartz reef about 12 in. wide in a country of slate and serpentine. The find is in the ranges about 6 miles southeast of Gundagai and yields about 3 oz. gold per ton. The report of the Broken Hill Block 14 Co., of New South Wales, notes that the substitution of briquetting and desulphurizing methods for their former roast processes has resulted in considerable economy. Three smelting furnaces are now doing the work that required five by the old method. The average grade of ore sent to the mill was Pb 16·7%, Zn, 12·4%, and silver 10·9 oz. per ton. The cost of treating the concentrates and slimes by briquetting proved to be one-half of the former cost of roasting. The company reports a total reduction of liquid assets of £9,559 for the half year ending September 30, 1901, due to reduction in the value of bullion and ore carried over from the previous half year, a considerable outlay at the smelting works, and the cost of development work at the mine.

New Zealand.—The gold production of this colony is showing an upward

trend which promises to attain in the near future the high water mark of the early days when the output was over $10,000,000 annually. In 1901 the production was 412,189 fine oz., valued at $8,519,947, against 338,902 fine oz. ($7,005,103) in 1900. The favorable condition of the industry is due to the successful working of medium grade ores and to the extended operations of the gold dredge. This appliance has been found very economical for working alluvial gravels, and a considerable portion of the total output of gold is now mined by this means, the amount recovered in 1901 being 65,531 oz. Otago and Westland are the principal alluvial districts, the former being the more important and containing the Kawarau and Molyneux rivers, the richest gold-bearing streams in the colony. Dredging operations are limited to a period of about six months during the winter season when the streams are at low-water. The number of companies registered is about 300, representing a capital of over $15,000,000. According to Mr. Raymond Payne[1] the ladder-bucket type of dredge is the one universally adopted, the other types having been found unsatisfactory. The maximum capacity of the buckets is 7 cu. ft. and the range or scope varies from 60 ft. below to 60 ft. above the water line. Recently an American firm, the Quintard Iron Works, of New York City, has secured a contract for the construction of four dredges which are to cost about $30,000 each and will have a capacity of 13,000 cu. yd. per week. It is estimated that the working capacity of each dredge will be about $264 per week, or, approximately, 14 oz. of gold, so that if a saving of one grain per cu yd. is made the net earnings will amount to $216 per week. Some of the dredging enterprises have been very successful from a financial standpoint, as is instanced in the reports of the stock companies, one of which shows a dividend distribution of 862% in two years. The returns from the Hauraki gold fields were very satisfactory, both as regards the older mines and those under development. The Waihi Gold Mining Co., Ltd., during 1900 treated 112,012 tons of ore for a yield of 69,348 oz. gold, 190,555 oz. silver, and 22,964 oz. base bullion, the whole product being valued at £310,316. The average content of the ore, according to assay, was 14 dwt. 5 gr. gold and 3 oz. 4 dwt. 21 gr. silver per ton, a slight reduction in gold as compared with the previous year. The net profits of the year's operations were £172,225 and the dividend distribution was £160,000 or 50% on the capital stock. The report of the Waihi Co. for 1901, shows a profit for the year of £232,480, out of which shareholders have received dividends to the amount of £166,425, being at the rate of 50% per annum. During the year 159,325 tons of ore were treated with a gold yield of £461,205. The gross revenue was £464,810, and the total expenditure £232,330. In examining a large number of sulphide ores of the Hauraki gold fields, Mr. F. B. Allen, in the *Transactions of the Australasian Institute of Mining Engineers,* 1901, found that in no case was the percentage of tellurium present sufficient to indicate in what combination it occurs, although in every ore containing copper, whether in small or large amount, the presence of tellurium was detected. The following analyses of ores containing tellurium were given: Coromandel, containing 25% mispickel, 200 oz. gold, 90 oz. silver per ton and a small percentage of tellurium; Tapu, containing dense iron pyrites

[1] *Engineering and Mining Journal*, Sept. 28, 1901.

and chalcopyrite, 2·25 oz. gold, 250 oz. silver, 7·5 oz. tellurium per ton. Waiomo, Broken Hill mine, 2 oz. gold, 30 oz. silver, and tellurium less than 1% of the bullion. Waiomo, Gem mine, white quartz, 15 oz. gold, 600 oz. silver and 12 oz. tellurium. Other results obtained indicated that tellurium was not present in the auriferous quartz ores in amount sufficient to affect the extraction of the gold. According to reports of the Mines Department the production of silver in New Zealand for the 11 months of 1901, ending November 30, was 466,793 oz., against 278,404 oz. for the corresponding period of 1900. The Department of Mines of New Zealand has offered a reward of £2,000 for the invention before January 1, 1904, of a machine for saving profitably 3d. of gold per cu. yd. contained in the black sands of New Zealand. The invention must differ from known appliances, must be readily transportable, and capable of treating a minimum of 30 cu. yd. per hour, and the patent rights to be inoperative in New Zealand. The plant must be operated for six months to demonstrate its success.

Queensland.—The gold production in 1901 was 576,920 fine oz., valued at $11,924,936, against 676,029 fine oz. ($13,973,736) in 1900, showing a decrease of 99,109 fine oz. in the year. This unfavorable result was due largely to the exhaustion of tailings heaps undergoing cyanide treatment, especially in the Charters Towers district, and to the severe droughts prevailing in parts of Queensland, which compelled the Mount Morgan Co. to curtail its operations. The outlook for the present year is favorable to an increased yield, but it is doubtful if the figures of 1900 will be attained. The report of the Mount Morgan Gold Mining Co., Ltd., for the year ending May 31, 1901, shows an output of 215,461 tons of ore, from which 173,833 oz. of gold, valued at £693,273, were obtained. The underground workings supplied 58,690 tons of sulphide ore and 14,177 tons of oxidized ore, and the open cuts supplied 149,384 tons of oxidized ore. Dividends amounting to £350,000 were paid and £22,279 was carried over to the following year out of a total income account of £734,867. The average yield per ton of ore was 16·13 dwt., or 0·48 dwt. per ton more than the average yield in 1900. Within the six months ending November 30, 1901, the output from the mine was 111,181 tons of ore containing 82,610 of gold, while the dividends declared were £116,666. The Charters Towers field reported a yield for the year of 204,783 oz. from 214,595 tons ore milled and 157,440 oz. from 381,668 tons sands treated in cyanide works, a total, after including the small amount of gold obtained from smelting and placer operations, of 366,431 oz., as compared with 454,679 in 1900. There was a falling off in the output from cyanide works of 80,495 oz., for which the decreased tonnage treated was accountable. Of the individual producers the Brilliant and St. George Gold Mining Co., the Brilliant Central, and the Day Dawn Block and Wyndham held the most prominent place, paying £156,000 in dividends. Development work was carried out which should have a favorable influence on the future yield of the district. The operations at Glympie were very satisfactory, the output, 111,061 oz. from 112,100 tons of ore being the highest recorded. The dividend distribution was £201,722. The returns from the Croyden field showed a total of 72,593 oz. recovered from 2,677 tons of quartz and 21,513 tons of residues.

South Australia.—The production of gold for 1901 was 21,939 fine oz., valued at $453,472, while the figures for 1900 were 25,713 fine oz. gold, valued at $531,498, showing a loss for 1901 of $78,026, which was due in large measure to the drought which was extended and severe over Australasia generally. Most of the gold obtained from South Australia continues to come from the mines owned and operated by the Chinese in the Northern Territory, and of the 1,304 men engaged in mining in 1900 in that part of the country, 1,226 were Chinese.

Tasmania.—The gold production for 1901 was 52,627 fine oz., valued at $1,087,800, showing a decline of 20,951 fine oz. ($433,057) as compared with the previous year. The largest mine in the colony is the Tasmania Gold Mining & Quartz Crushing Co., in the Beaconsfield district, which, during the year ending September 30, 1901, produced 33,434 oz. gold, valued at £127,157 from 24,640 tons of ore. A marked falling off was noted in the returns for September, which was attributable to the exhaustion of tailings stocks undergoing treatment by the chlorination process. Forty head of stamps are being added to the present battery of 65, nearly doubling the crushing capacity. In the semester closing September 30, 1901, the Mount Lyell Mining & Railway Co. extracted 135,511 tons of ore from its mines, which gave an average assay of 2·35% copper and 2 oz. silver and 0·065 oz. gold per ton. The amount of gold recovered from blister copper was about 10,000 oz. At the New Golden Gate mine in the Mathinna district, new ore bodies were found on the 1,000-ft. and 1,400-ft. levels, and it was decided to extend the main shaft to 1,600 ft. This district is second to the Beaconsfield in importance.

Victoria.—The production of gold for the year 1901 was 743,467 fine oz., valued at $15,367,643 against a production for 1900 of 807,407 crude oz. (760,142 fine oz.) ($15,712,140), a decrease for the year in value of $344,677. On January 1, 1901, there were 29,410 men employed in gold mining, and 10 hydraulic dredging plants in operation, while the 103 gold-dredging leases in force occupied but 5,903 acres of the 100,000 acres available for alluvial working in the State. While there are seven mining districts in Victoria, three of them—Ballarat, Bendigo, and Beechworth—produce nearly two-thirds of the total gold yield of the State. The gold recovered from quartz represents 67·2%, and that from alluvial deposits 32·8% of the whole. Victoria has continued its policy of road building, having added over 100 miles during 1900 at the expense of the State.

Western Australia.—There was a general improvement in the gold mining industry from the unfavorable conditions prevailing in 1900, and the output showed a large gain. The total yield for 1901, as reported by the Governmental authorities, was 1,700,980 fine oz., valued at $35,159,257, against 1,414,273 fine oz. ($29,233,035) in the preceding year, this being the highest figure yet recorded in the history of the Western Australian gold fields. The chief factors contributing to the large increase were the opening of several new mines, the extension of operations by the established enterprises, and the partial solution of the problem of dealing with the low-grade sulphide ores. Some progress was made in lowering the cost of ore treatment by the different companies, although this feature is not reflected in the dividend payments.

which were less than in 1900. The East Coolgardie field as usual held first place in respect of output, the Mount Margaret, Murchison, North Coolgardie, and Coolgardie fields following in the order mentioned. The Lake View Consols, Ltd., reports for the year ending August 31, 1901, show the tonnage treated by the Diehl process, introduced early last year, at 41,054, the product from which was 40,121 oz. in gold bullion, and 1,601 tons of concentrates containing 21,217 oz. gold, which were treated at the Freemantle Smelting Works. The average costs during the time the Diehl process was in operation, without counting realization on concentrates, was 28s. 3d. per ton. In addition 160 tons of oxidized sands and 15,733 tons of oxidized slimes were treated early in the year, with a saving of 43, and 6,793 oz., respectively, which exhausted the supply of this class of material. The total output of gold for 1901 was 121,684 oz., approximately, valued at £461,584, made up as follows: Furnaces, 53,251 oz.; oxidized sands and slimes, 6,836 oz.; Diehl slimes, 40,121 oz.; Diehl concentrates, 21,217 oz.; slags, 259 oz.; total, 121,674 oz. Additions to the plant making a capacity of 12,000 tons of ore per month are contemplated. According to the report of the Great Boulder Perseverance Gold Mining Co., Ltd., in 1901, 108,355 tons of ore and 32,240 tons of tailings were treated, yielding gold valued at £487,733, as compared with £160,368 the previous year, extracted from 42,297 tons of ore, and 25,990 tons of tailings. The costs per ton at the sulphide plant have been reduced from 34s. 11·5d. in 1900, to 24s. 10·5d. in 1901. At the annual meeting of the company it was decided to charge off the whole cost of the plant, £161,390, which allowed £8,224 to be carried forward. In development £31,977 was spent during 1901, against £28,338 for 1900. The main shaft has now reached a depth of 1,000 ft. The Great Boulder Proprietary Mines Co., Ltd., has proved its ore body for a total depth of 1,300 ft., or 200 ft. below sea level, which is the greatest depth thus far attained in Western Australia. During the fiscal year ending August 31, 1901, 54,887 tons of ore was treated, with a saving of 115,909 oz. of gold. An interim report for 1900 shows a net profit of £250,139 during the year, from which sum must be deducted a total taxation of 10% from the English Income and Australian Revenue taxes. The expenditure was greater during the year, owing to the introduction of the new sulphide plant and the larger amount of slimes treated and handled. The Ivanhoe Gold Corporation announced early in 1901 that no dividends would be paid at present, owing to the necessity of holding cash on hand for expenditures in development and to make provision for the installation of a new sulphide plant. In 1900 this company treated 74,750 tons of ore, yielding 107,052 oz. gold, an average of 1·43 oz. per ton treated. The plant of the company includes 61 stamps, 16 leaching vats of a capacity of 80 tons each and 4 filter presses. In 1900 the Golden Horseshoe Estates, Ltd., treated 76,532 tons of ore which yielded 132,863 oz. of gold, an average of 1·73 oz. per ton treated. The equipment of this plant includes 55 stamps, 29 leaching vats of a capacity of 70 tons each, and 9 filter presses. The Pendinnie Gold Mines, Ltd., was organized late in 1900 to take over five leases on an area of 84 acres in the Yerilla district, from the London & Hamburg Gold Recovery Co., Ltd., the owner of the Diehl sulphide process. The Diehl process seems to have scored a decided success in the Kal-

goorlie district, the costs of treatment per ton of ore have been reduced in a number of instances, and familiarity with the details of the process has revealed few problems for future economies. The percentage of concentrates (10 to 12%) produced compels a subsequent smelting process, in which gold losses may occur, but in general this process appears to have successfully solved the problem of treating the refractory telluride ores. The successive steps of the Diehl process are: Wet-crushing and amalgamation of free gold; concentration and subsequent separation of the sands and slimes; regrinding the sands until both sands and slimes will pass a 120-mesh screen; agitation of the slimes with bromo-cyanogen; and finally, filter-pressing, to recover the solution. The ores are crushed and amalgamated in stamp batteries, concentrated on the ordinary wet-concentration tables, and the sands are re-ground in tube mills. The lowest cost so far claimed for the process is 21s. per ton of ore treated which of course includes plant management, etc., and the greatest recovery claimed is 97% of the gold content of the ore. A further account of this process will be found under the caption "A Review of Progress in the Cyanide Process during the Year 1901" elsewhere in this volume.

New Guinea.—A German company has received a concession for the exploration of a large extent of territory in Kaiser William's Land which is thought to be gold bearing. In British New Guinea there are placer deposits that yield a small amount of gold annually, the export during the fiscal year 1899-1900 amounting to 9,256 oz., valued at $162,390. On Woodlark Island discoveries of a gold-bearing formation have been made and a 20-stamp mill to treat the ore is now in course of erection.

Progress in Gold Milling during 1901.

By R. H. Richards.

Gold Milling.

The Bryan Mill.[1]—D. W. C. Nelson states that the Bryan mill has saved as much as 75% inside the mill, the principal part of the amalgam collecting in the eddy between the die and the central cone. The mill has an advantage over stamps in that it does not slime the ore, which assists the subsequent concentration. The capacity of the mill is from 5,000 to 8,000 tons of Baker County (Oregon) pyritic ores with one set of wearing parts; and with hard ore a 5-ft. mill will crush in 24 hours as much as ten 850-lb. stamps. With these ores best work was done with the No. 8 slot Russia iron screen.

Huntington Mills.[2]—The original form of the Huntington at the North Boulder mill, West Australia, showed a gold yield of about 78%. The capacity of a 5-ft. mill is from 13 to 14 tons per 24 hours; the screens are No. 40 diagonal slot without buhr; the mill makes from 65 to 70 revolutions per minute, uses 700 gal. of water per hour, and is charged with 70 lb. of mercury. At the Great Boulder mill the mercury loss is from 0·425 to 0·470 oz. per ton of ore treated.

Tremain Steam Stamp.—Experience shows that a steam stamp of this type in 24 hours will pulverize from 10 to 15 tons of ordinary gold quartz to 40-mesh. The power varies from 7 to 10 H.P., depending upon the speed at which the stamp is run. The water required for the mill and boiler is 800 gal. per hour, or better, 1,000 gal. if sufficient can be had. The screen area is 450 sq. in. as against 475 sq. in. of a battery of five gravity stamps. A recent installation of eight Tremain stamps has been made.[3] A comparison of power and capacity shows a steam stamp mill of eight stamps is equivalent to 40 gravity stamps.

Prospecting Steam Stamp Mill.[4]—A mill of three 40-lb. stamps, dropping 250 times per minute, is capable of crushing about 4 tons of quartz per day. The entire outfit complete, with boiler, plates, etc., without the road carriages, weighs about 7,100 lb., and costs about $1,250. At the Coolgardie Exhibition, in 1899, this mill crushed 50 tons, averaging 4·07 tons per 24 hours; 83·5% of the gold content was saved by amalgamation.

Snodgrass Pulverizer and Concentrator.—This apparatus, made by S. K. Snodgrass, Denver, Colo., is used to save gold, and consists of the following parts arranged in series: (1) a horizontal iron trough 26 in. in diameter and 18 ft. long; (2) a revolving screen; (3) a second trough 26 in. in diameter and 12 ft. long. In each trough is a strong revolving shaft to which are attached projecting teeth of white iron arranged spirally, their action being to disintegrate the material and to carry it forward at the same time. The revolutions per minute are from 150 to 250 for the first shaft, and from 300 to 500 for the second. A space of about 4 in. between the ends of the teeth and the bottom of the troughs fills up with sand and gravel, and it is claimed that the free gold settles. The ore fed at the end of the first trough passes through and leaves some of the gold in the

[1] *Transactions of the American Institute of Mining Engineers*, Vol. XXX., 1901.
[2] A. G. Charleton, *Engineering Magazine*, Vol. XXI., 1901, p. 405.
[3] Philip R. Björling, *Feilden's Magazine*, Vol. III., 1900, p. 559.
[4] *Feilden's Magazine*, Vol. V., 1901, p. 167.

bottom. Thence it falls into the screen and the coarse material is removed and sent to the dump; the fine material undergoes a second treatment in the second trough. The machine has been used successfully in Colorado.

Foundations.[5]—It is claimed that a rock foundation is not necessary for stamp mills, as one of concrete has been used successfully. Attention is called to the following points of this style of foundation: (1) the foundation pit should be sufficiently deep to allow the material at the bottom to become homogeneous; (2) allow 25 sq. ft. at the base for five stamps, and 60 sq. ft. for 10 stamps; (3) use best Portland cement and concrete of four parts clean sand, two parts broken granite, one part Portland cement; (4) the concrete foundation should be not less than 30 in. thick; (5) finish off with one part sand and one part cement.

Battery Construction.[6]—Mr. C. G. Warnford Lock calls attention to the difficulty encountered in the removal of worn-out mortar boxes caused by the rusting of anchor bolt nuts, and suggests that the anchor bolts, instead of traversing the mortar blocks, should occupy shallow recesses cut in their surface, and should be looped at the lower ends to encircle a short length of 1·5-in. iron pipe which is driven into an auger-hole extending through the blocks from front to back. During five years' wear in a battery with weak foundations and excessive vibration, this anchorage gave entire satisfaction and afforded every facility for mounting and dismantling the boxes; the same principle may be applied to concrete blocks.

Iron Guides.—As a result of several years' experiments by Mr. Robert Canning[7] a simple cast-iron box was adopted which was turned true in a lathe and finished with a perfectly smooth wearing face. A guide so made lasted for three years without repairs. The stems never became even warm to the touch, while with wooden guides they were always quite hot; the consumption of lubricant is reduced more than half.

Power Required by Stamps.—Mr. A. W. Warwick[8] gives in detail the formulæ necessary for calculating the power required by stamps. Previous formulæ for calculations did not come within 30% of the actual power used, probably because the inertia of the stamp was not considered. By allowing for this factor, results can be obtained which check within 2·5% of the actual power used. Courtenay de Kalb[9] has found that 32% is the average amount of ore, under ordinary working conditions, that passes through a 100-mesh sieve after crushing in a stamp mill. He advocates increased amalgamation inside the mortar and thinks it a good rule not to allow 60% of the amalgamable gold to escape through the screen. The adoption of a positive ratio would seem impossible; if the gold was very coarse, the ratio would come higher than that advised by Mr. de Kalb, and if very fine, it would be impossible to reach.

Electro-Silvered vs. Plain Copper Plates.—Mr. Jas. R. Cooper[10] raises the point that Mr. Halse's[11] tests were not convincing because the grade of copper was not

[5] *Mining and Scientific Press*, Vol. LXXXII., 1901, p. 95.
[6] *Institution of Mining and Metallurgy*, Vol. IX., 1901, p. 310.
[7] *Ibid.*, p. 312.
[8] *Mining and Scientific Press*, Vol. LXXXII., 1901, p. 103.
[9] *Journal of the Canadian Mining Institute*, Vol, IV., 1901, p. 190.
[10] *Engineering and Mining Journal*, Vol. LXXI., 1901, p. 330.
[11] A paper read before the Institution of Mining and Metallurgy, Vol. IX., 1900, p. 155. See also THE MINERAL INDUSTRY, Vol. IX., 1901, p. 353.

stated. The chief impurity of commercial copper is oxygen, and it is the belief of Mr. Cooper that a deoxidized copper plate can be made which will be equally as good as a silver-plated copper plate.

In reply, Halse[12] states that while no analysis of the copper plate is available, it was of good quality, being that commercially known as "brazier's copper." The annealing was carefully done, and the whole surface of the plate scoured to bright copper before amalgamating. He thinks that the staining was not due to impurities in the original copper, although he is unable to give positive proof.

Water Economy.[13]—This factor is very necessary in stamp milling in the arid districts of the Southwest. The two common methods are the dam and reservoir and the settling tanks; the former will save about 50% of the water, while the latter saves about 85%. A useful device for a coarse concentrating mill is an old jig fitted with a fine screen of coarse wire: all compartments are thrown into one and the plungers are fitted with a simple valve which partially exhausts the air from below the screens; the tailings and water are led to the jig, the water being sucked into the hutch, while the tailings are removed by a screw conveyor to a conveying belt and thence to the tailings pile.

A statement of the amount of water used to mill a ton of ore in different mills is made in the following table. Owing to the varying conditions any comparison will be approximate.

Name and Locality of Mill.	Capacity per Day.	Method of Saving Water.	Amount of Water Lost per Ton of Ore.	
			With Saving.	Without Saving. (Estimated.)
	Tons.		Gallons.	Gallons.
Yellow Aster, California.	520	Settling pond.....	500	1,250
Congress, Arizona.....	140	Settling tanks emptied by shoveling..	259	2,000
Tennessee, Arizona.....	75	Settling tanks emptied by shoveling..	155	2,000
Pinos Altos, New Mexico	100	Settling pond.....	1,200	3,000

Lake View 50-Stamp Battery (West Australia).—According to A. G. Charleton,[14] ore is crushed by a Gates breaker at the shaft, and conveyed by a rope tramway to the mill. The 900-lb. stamps drop 6 in. 90 times per minute, and are fitted with gib tappets; in 1898 the duty per stamp per day was 4 tons. Gold is caught on amalgamated copper plates and canvas tables and the tailings are cyanided. The cost per ton in 1898 was 10s. 1·2d. ($2·46); and in 1899 it was 6s. 10·463d. ($1·67).

The Morro Velho Stamp Mill, Brazil.[15]—This mill has 120 stamps fitted with double discharge mortars. The stamps weigh 800 lb., and drop 8 in. from 80 to 85 times per minute; 60-mesh corrugated screens are used. The pulp after leaving the amalgamated plate passes to a distributor, thence to straking and automatic washing area. About 80% of the gold is retained on the plates with the richest pyritic sand, which, after further concentration passes to steel amalgamation barrels lined with wood. Each barrel contains 2·7 tons of concentrates which is charged with 50 lb. of mercury and a certain quantity of water; amalgamation is complete in about 12 hours; the extraction averages 70% of the

[12] *Engineering and Mining Journal*, Vol. LXXII., 1901, p. 464.
[13] *Engineering and Mining Journal*, Vol. LXXII., 1901, p. 225.
[14] *Ibid.*, p. 405.
[15] *Engineering and Mining Journal*, Vol. LXXII., 1901, p. 485.

assay value of the ore. The barrels discharge to separators, and the sand goes to the so-called "Oxygen Process," which extracts from 70 to 80% of the remaining gold content.

Gold Milling Practice at the Athabasca Mine, Nelson, B. C.[16]—The ore carries free gold closely associated with blende and galena. Ten 980-lb. stamps drop from 5 to 8 in. from 80 to 115 times per minute; the height of discharge is 6·5 to 11·5 in.; a diagonal slot punched screen is used. With new dies a 50-mesh screen is used, after 30 days a 40-mesh, and when dies are well worn down a 30-mesh. This is done because inside amalgamation is desired, the level of discharge being maintained constant and the increased height of discharge is compensated for as the dies wear down. The maximum crushing capacity is 2·33 tons per stamp per day. Inside amalgamation yields from 30 to 45% of the bullion, as against 20% from the outside lip and apron plates. Outside plates are dressed five times every 24 hours, and the amalgam is removed from the apron plate every two days; the lip plates are cleaned and the mortar opened and cleaned of refuse every sixth day; the inside amalgam is removed during the monthly clean-up. The total time lost from monthly clean-ups aggregated eight days and 17 hours in one year. The pulp from the plates is sized in a cone sizer, the coarsest product goes to a 4-ft. corrugated belt vanner, the three other sizes are treated on separate 6-ft. plain belt vanners. The tailings are cyanided.

Cheap Gold Milling at Chiapas, Mexico.[17]—The ore is soft and of low grade, averaging in value 0·2 oz. per ton of 2,240 lb. It is crushed in a 10-stamp battery with 750-lb. stamps dropping 5 in. 100 times per minute; a 40-mesh screen is used, and there is no inside amalgamation. The extraction averages 30%, due to the fact that a portion of the gold is covered with iron oxide. The cost of milling is 17·6c. per ton of 2,000 lb., not including power—the whole mill being driven by water power.

Treatment of Auriferous Mispickel Ores at Deloro, Ontario.[18]—The ores are generally quartz, more or less heavily impregnated with arsenopyrite, occasionally with copper pyrites and frequently with large percentages of pyrites. At the shaft-house the ore passes to the grizzlies; the oversize is sorted, the white quartz being returned to the mine, where it is used as stope filling, and the remainder, with the undersize, passing to the mill. The stamps are 20 in number, each weighing 850 lb.; the height of discharge is from 6 to 8 in.; 10 old stamps drop from 7 to 8 in. 100 times per minute, and have a capacity of 3 tons per stamp per day; 10 new stamps drop from 6 to 7 in. 110 times per minute, and have a capacity of 4 tons per stamp per day. A 40-mesh buhr slot screen is used, which lasts from 10 to 18 days. Inside amalgamation averages 20% of the assay value in gold. Heavy silver plating, 4 oz. per sq. ft., is best for this ore. Inside and outside amalgamation saves on an average 57% of the assay value. From the old 10 stamps the pulp goes to two corrugated belt vanners, thence to classifiers, the three products of which are treated on smooth belt vanners. The tailings average from 2 to 2·5% of the original gold content, and 0·5% of the original mispickel content of the ore. The pulp from the new 10 stamps passes to two Wilfley tables,

[16] *Journal of the Canadian Mining Institute*, Vol. IV., 1901, p. 88.
[17] *Transactions of the American Institute of Mining Engineers*, Vol. XXX., 1901.
[18] *Journal of the Canadian Mining Institute*, Vol. IV., 1901, p. 118.

thence to a classifier, producing coarse sand, which passes to a Bartlett table, the overflow passes to the three-compartment classifier. All concentrates are treated at the leaching plant by the bromo-cyanide process, and are calcined afterward for the arsenic content.

Improved Amalgamation Process.[19]—The object of the process is to increase the percentage of extraction of gold by amalgamation by passing ammoniated air, mixed with either chlorine or bromine into the wet pulp. A number of tests have been made at the testing works of Henry E. Wood, Denver, Colo., and in all cases an increase in the amount of gold extracted by amalgamation was obtained. At a test made at the Anderson mill at Idaho Springs, Colo., with gold ore containing $10 per ton, the ordinary tailings showed a value of $4 gold per ton, while the tailings of the ore treated with ammonia gas showed a value of $1·80 per ton. It is presumed that Mr. Wood has obtained his results by weighing the increased bullion obtained and not by the assay of tailings. Otherwise the gain might not be proved.

Crown Mountain Mill, Georgia.[20]—At this mill four giants are used for breaking down saprolite carrying free gold. The detritus from hydraulicking along with the broken ore from vein mining is transported to the mill by a sluice which in one place is cut, the continuing section being dropped 4 ft.; grizzlies with 0·75-in. spaces are introduced at this point. The undersize continues with the water and goes to settling bins for subsequent treatment in Huntington mills. The overflow goes to a Frazer & Chalmers gravel-pan designed to catch any fine gold that may have passed the riffles in the sluice. The oversize from the flume grizzlies falls into bins, and is trammed to the mill breaker, a Dodge, thence to the battery bins. The stamp mill consists of 10 batteries of five stamps each. The pulp passes over silver-plated copper plates, thence to Wilfley tables; the Huntington mills are also equipped with plates and Wilfley tables.

Gold Dredging.

Dredging Practice at Oroville, Butte County, Cal.[21]—This practice is discussed in detail by G. P. Grimsley. Four types of dredges are in use in California: (1) Risdon, (2) Bucyrus, (3) Urie, and (4) Marion.

The Risdon Dredge consists of a strongly framed hull of Oregon pine, in which the machinery is housed; at the forward end is the ladder consisting of a heavy lattice girder on which runs the endless chain elevator carrying buckets of from 3 to 5 cu. ft. capacity; the buckets have renewable nickel-steel lips. The belt travels over a square-top tumbler, and is driven from a train of gears and one belt from a 50-H.P. induction motor taking a tri-phase current at 1,000 volts; 25 H.P. is consumed when dumping 12·5 buckets per minute, giving a capacity of 150 cu. yd. per hour. The material from the buckets goes to a delivery plate, thence to a revolving screen, 4 ft. in diameter, 24 ft. long, perforated with 0·75-in. holes. The oversize goes to a stacker (bucket elevator) at the stern of the boat, which, together with the screen, is driven by a 20 H.P. induction motor. The undersize from the screen goes to a distributing box and over 300 sq. ft. of tables

[19] *Engineering and Mining Journal*, Vol. LXXII., 1901, p. 108.
[20] *Ibid.*, p. 355. [21] *Ibid.*, Vol. LXXI., 1901, p. 823, and Vol. LXXII., p. 40.

made of cast iron covered with cocoa matting and expanded metal riffles. Most of the gold is caught in the first 9 in. The overflow goes to a sluice-box containing angle-iron riffles. Water is supplied by two centrifugal pumps requiring 30 H.P., one delivering 2,000 gal. per minute through a perforated pipe into the screen, and the other supplying the various grizzlies and the distributing box.

The Bucyrus Dredge is of the continuous bucket type, equipped with buckets of 3, 5, and 7·5 cu. ft. capacity. There are two types, single and double lifts. In the former the gravel is elevated in one lift sufficiently high for subsequent operations, while in the latter, the fines from the revolving screen are re-elevated by a centrifugal pump to the gold-saving tables. A crew of two men per shift and 200 H.P. are required on a 5-cu. ft. bucket machine. A double lift dredge on a six months' run averaged 2,200 cu. yd. per 24 hours, including all shut downs.

The Urie Dredge is of the endless chain belt type, with buckets of from 3 to 4 cu. ft. capacity, fitted with an automatic feed device by which they may be entirely or only partially filled. A dredge of this type with a capacity of 1,500 cu. yd. per day is driven by six independent steam engines using steam from two 50-H.P. boilers.

The Marion Dredge is of the dipper or steam shovel type, with dippers of from 1·25 to 2·5 cu. yd. capacity. The 2·5-cu. yd. machine is run by a 100-H.P. motor; the screens and side conveyor require a 10-H.P. motor; the tailings stacker requires a 10-H.P. motor; and the pumps require a 30-H.P. motor, making a total of 150 H.P.

The costs of dredging gravels on the Feather river range from 4 to 12c. per cu. yd. Twenty-five companies operate 26 dredges, and eight more are ordered. Of those in operation at the end of the year, 14 are Risdon, three are Bucyrus, three are Marion, two are Urie, and three are steam shovels. The estimated cost of a 5-cu. ft. bucket dredge is about $25,000, which will work about 10 acres of gravel 30 ft. deep per year. Prospecting of gravel beds in California is now done almost entirely by Keystone drills.

The Nome District.[22]—The non-success of dredging in the Nome district has been due partly to severe climatic conditions and partly to machines unsuited to the conditions. The ground adapted for dredging is in narrow water channels. A contributing cause of failure in beach dredging has been the heavy surf.

The Knott dredge, which has been successful on canal work, is to be tried. This type of dredge has the advantage of being able to swing the ladder through 180° without moving the hull; this adapts it for waterways no wider than the hull. The lower drum over which the buckets pass has no guide flanges, but is equipped with an automatic device, so that when an obstruction is encountered the drum rises, and after the obstruction is passed it adjusts itself automatically.

New South Wales.[23]—In this State the inclined tables receiving material passed through the trommel, are covered with cocoa-matting, upon the top of which wire netting or expanded metal netting,—the latter is made of wrought iron,—is placed, and forms riffles to catch the gold. To collect the concentrates the cocoa-matting from the first table is rinsed in a box of water every night, and

[22] *Engineering and Mining Journal*, Vol. LXXI., 1901, p. 785.
[23] *Canadian Mining Review*, Vol. XX., 1901, p. 176.

those from the other tables once a week. The washings, or concentrates, are then treated in a "streaming-down box" and the gold separated from the worthless material.

The New Zealand Bucket Dredges.—A. C. Perkins[24] describes the types now in use. They differ but little from the American or Australian prototype; the gold saving appliances also are similar. Under favorable conditions costs run as low as 1·6c. per cu. yd. When working in unfavorable ground engine diagrams taken showed a variation in load of from 45 to 70 H.P. in three revolutions.

An Aid to Gold Dredging.[25]—This consists of an addition to the standard dredge of a pneumatic tube which may be raised or lowered through a depth of 65 ft., the lower mouth of the tube is placed on bed rock and the water expelled by compressed air. The tube is large enough to carry a track-way on which runs a track for hoisting boulders and bed-rock cleaning. The lower end of the tube is enlarged to allow men to work, and the upper end has the customary air-lock entrance.

Pelton Wheels.[26]—Water-wheels of this type have been substituted for steam power on the Consolidated dredge operating at Waipori, New Zealand. They have proved a complete success.

Method of Saving Fine Gold of Snake River, Idaho.—Mr. Wm. H. Washburn[27] describes some of the methods out of which have been evolved the processes now most successfully used for saving the fine gold of the Snake river. For many years a modified form of the rocker was used, usually of sufficient size to have burlap and silver-plated copper plates, the latter being placed in the bottom. Later the so-called "beach machine" found much favor, as it did not require motion; it consists of a sheet-iron screen set at an angle of from 25° to 30°, having below at a reduced angle a silver-plated copper plate, which catches most of the gold; the material passing from it is conducted to a table or sluice to catch the rusty gold. Much of the mining on a small scale is now done by these or similar machines. Another device is to cover the bottom of a sluice 6 to 12 in. wide with Canton flannel over which is placed a stout wire screen with 0·25-in. holes; the sluice should be cleaned often enough to prevent loss of black sand which is accompanied with gold.

In September, 1899, with coal at $7·50 a ton, a dredge was operated at 3c. per cu. yd., not including wear and tear.

After reviewing the results of the methods used at Snake river, Mr. Washburn concludes: "First, the sand should be screened to as near the size of the coarsest particles of gold possible; second, to save all the gold the black or other heavy sand should be saved with it; third, it is necessary to scour the gold in the concentrates by some form of grinding. With these principles carefully and intelligently carried out there seems no reason why the percentage of gold saved should not be as high as 90%, or even 95%."

[24] *Mines and Minerals*, Vol. XXI., 1901, p. 350.
[25] *Mining and Scientific Press*, Vol. LXXXII., 1901, p. 94.
[26] *Engineering and Mining Journal*, Vol. LXXII., 1901, p. 682.
[27] *Mining and Scientific Press*, Vol. LXXIII., 1901, p. 45.

A Review of Progress in the Cyanide Process during the Year 1901.

By J. S. C. Wells.

The cyanide process has made very decided progress during the past year, especially in the United States and in Canada. A large number of plants have been erected, some being of considerable size, notably the new Homestake plant, with a capacity of 1,200 tons per day and the Smuggler-Union plant of 600 tons daily.

The slimes problem seems to have been very successfully solved in several works, the process used in almost all cases being some modification of agitating and settling.

A good example of dry crushing and slimes treatment is that of the Cochiti Gold Mining Co., of Bland, N. M., a description of which was given in the *Engineering and Mining Journal,* January 19, 1901. A few mills using wet crushing with cyanide solution in the mortars are in operation and the results are said to be satisfactory.

No improvements in the precipitation of gold and silver from cyanide solutions have been developed and in this country the process of precipitation with zinc shavings appears to be the favorite, although zinc dust is being used successfully by several large mills. The Waldstein or De La Mar patent covering the use of the latter substance has been declared invalid by the United States District Court of Idaho, and it is probable that the use of this method will increase, for it has some decided advantages over zinc shavings, yielding a much finer bullion and at no greater cost; furthermore the precipitation seems to be rapid and complete. The chief difficulty is in making it a part of a continuous process. The following mills treating in all over 3,000 tons per day are using zinc dust for the precipitation of the gold: Homestake Mining Co., South Dakota; Montana Mining Co., Montana; Republic Mining Co., Washington; De Lamar Mining Co., Idaho and Nevada; Chainman Mining & Electric Co., Nevada, and the Consolidated Mercur Co., Utah. The price of zinc dust is $6 to $7 per cwt., and the amount used is from 6 to 9 oz. per ton of solution.

The progress of cyaniding is summarized by States as follows:—

California.—The California King Mines Co. has recently contracted for a 1,000-ton mill at Picacho, 20 miles north of Yuma, Ariz. The ore will be crushed by rolls to 20-mesh size and treated in 10 cyanide tanks 40 ft. diameter and 5 ft. deep. After leaching, the tailings will be sluiced through bottom gates. The Golden Cross mines have a 140-stamp mill and large cyanide plant at Hedges, 25 miles northwest of Yuma. The Standard Consolidated Mining Co., at Bodie, treats ores containing so much clayey matter that about 45% run off as slimes. The process now in use is as follows: There are two tiers of vats and the tailings from the mill are run directly into the upper ones, from which the slimes overflow and run into settling ponds. During the year ending February 1, 1901, 10,067 tons (dry weight) of sands were treated, the extraction being 89·8% gold, and 41·8% silver. The consumption of cyanide was 1·65 lb., zinc 0·79 lb., lime 8·7 lb., per ton. The slimes of which, 5,878 tons (dry weight), were treated, are after settling and drying, mixed with a certain percentage of leached

sands and treated in the usual way. The extraction is 80·3% gold, 75·9% silver. Cyanide used 0·9 lb., zinc 0·64 lb., lime 7·78 lb.

The following mines are reported as having erected cyanide plants during the year:—

Calaveras County.—Keystone, 20 tons, and Calaveras group, the capacity of the latter is said to be large.

Eldorado County.—The Vandalia mine, 400 tons.

Kern County.—At the Exposed Treasure and St. John's mines, small plants.

Mariposa County.—The Hite mine, 100 tons.

San Diego County.—The American Girl mine, near Ogilby, 200 tons. The ore is crushed by Cornish rolls.

Trinity County.—Headlight, 200 tons, and Golden Jubilee, 20 tons.

Tuolumne County.—At the Eagle-Shawmut and Densmore, new plants.

Shasta County.—Mount Shasta Co., 50 tons.

Siskiyou County.—Golden Jubilee, 50 tons.

An example of what may be done by coarse crushing is given in the Cummings mine, near Callahan's, Siskiyou County. The gold in the ore is in an extremely fine state of division and by amalgamation yields only from 13 to 17%. The dry crushing plant which was installed was discarded after several months' trial, owing to the large amount of fines produced making the pulp so slimy that it could not be leached. It was then decided to try leaching the ore after it had been crushed to pass a grizzly set with bars 1 in. apart; the greater part of the material however was 0·25 in. or finer. The consumption of cyanide was 0·5 lb. per ton of ore and the time of treatment was from 72 to 90 hours, giving an extraction of 80%. The ore is oxidized iron pyrites.

Colorado.—The Smuggler-Union Mining Co. has a mill under construction which will treat 600 tons of tailings per day. The process will be similar to that used at the Liberty Bell, having the collecting vat placed above the leaching vat, using zinc precipitation, etc.

The new Dorcas pneumatic cyanide mill at Florence has a capacity of 120 tons per day. The ore averaging $20 in value passes through crushers and coarse rolls to the sampling room, thence through a revolving dryer and through two sets of finishing rolls which crush it to 24-mesh size. The finely crushed ore is then roasted in a Holthoff-Wethey furnace, the product passing to the leaching tanks. Six tanks 30 ft. in diameter, 4·5 ft. deep, are fitted with air pipes in the bottom for the introduction of air during the leaching. The air is supplied at a pressure not exceeding 5 lb., about 1 cu. ft. of air per minute to each ton of ore being sufficient for agitation and oxygenation. The treatment generally lasts five days and leaves a value of about $1 per ton in the ore. The residue is then sluiced out and concentrated on Wilfley tables. The tailings after this treatment average about 40c. per ton. The tanks are filled by a conveyor, and as soon as the bottom of the tank is covered with pulp a solution containing 10 lb. KCN per ton is run in gradually, the pulp at the same time continuing to flow in until the tank is full. The air is then turned on gradually and is kept on until the pulp shows an extraction of at least 90%. This generally requires about 30 hours. Whenever the air comes up unevenly through the

charge the ore has to be stirred by men with iron rods. The air is then shut off and the pulp allowed to settle for one hour. Percolation is then begun and the strong solution run off as quickly as possible, followed by a weaker one of 5 lb. KCN per ton. The operation is continued until the tests of the solution show only traces of gold. Water is then added to displace the KCN solution. The loss in cyanide is stated to be less than 1 lb. per ton. The dust resulting from the dry crushing is collected and treated with cyanide, without previous roasting. From dust assaying $51·20 per ton the tailings contained 80c. per ton. It is added to the roasted ore in the leaching tanks, 3 tons to each tank spread evenly on top of the charge.

The Peck cyanide mill treated Smuggler-Union and Marshall Basin tailings, and during the year its capacity was increased from 100 tons to 200 tons per day.

A number of small plants have been erected and operated during the past year in various sections of the State.

Dakota.—(By Charles H. Fulton.)—The condition of the industry is very prosperous, and the process is the dominant factor in the development of the Black Hills. The ores treated, with the exception of the Homestake tailings, are mainly of the siliceous Potsdam variety. This is quartzite carrying from 2 to 6% pyrites in the unoxidized ores. Considerable of the ore is oxidized and is the simplest to treat. But a very small percentage of the values in these ores are free milling. The unoxidized or pyritic ores, are known locally as "blue ores" from the bluish cast of the quartzite. In the Ragged Top district (Preston) where the Spearfish Gold Mining Co.'s plant and the Deadwood Standard Co.'s plants are located, the ores occur in the Carboniferous, and are mainly a siliceous limestone. The gold seemingly occurs on the cleavage planes of the rock in very fine films, allowing of very coarse crushing. The Potsdam ores, while all of the same general nature and appearance, are still widely different as regards the occurrence of the gold in them. Some have the gold on the cleavage planes, as in the limestone, as at the Wasp No. 2 cyanide plant on Yellow Creek, while others, as from Portland and Bald Mountain, have the values very finely disseminated, requiring very fine crushing. This explains the wide difference in the design of plants in the district. A few of the quartzite ores at Yellow Creek carry some antimony in the form of stibnite, however, not sufficient to cause difficulty in cyaniding. F. C. Smith considers tellurium as being often present in the Potsdam ores; if this be so, no attention has yet been paid to it in cyaniding. So far, all the ores cyanided are treated raw, although one of the new mills is installing a roasting furnace to treat the more refractory "blue ores."

Two methods of cyaniding, exclusive of the Homestake type, are in vogue: (1) Dry crushing by rolls, cyaniding the resulting pulp; and (2) Wet, fine crushing by stamps with cyanide solutions, separating the crushed product into sands and slimes by means of settling boxes, leaching the sands in the usual way, and treating the slimes by agitation and decantation.

Agitation is obtained by pumping from one tank to another by means of a sand or centrifugal pump, similar to the New Zealand practice. The crushing

by rolls in the dry mills varies much in fineness, some of the mills crushing to pass a 6-mesh screen, while others crush to pass a 16 to 20-mesh screen. This is necessitated by the dissemination of the gold. There are two mills using the wet crushing method, one the plant of the Dakota Mining & Milling Co., at Deadwood, and the other the Portland mill at Gayville, 2 miles from Deadwood. The rest of the mills in operation, as well as those in the course of construction, with the exception of the Homestake tailings plants, are dry crushing.

The Homestake Co.'s 1,200-ton tailing plant at Lead takes the tailings pulp from the Golden Star, Eighty, and Highland stamp mills. The pulp is conveyed to the cyanide plant in a 10-in. cast-iron pipe. On its way it passes through the classifier house, where some of the slimes are separated by means of eight large sheet iron cone-shaped classifiers. These cones have no upward or rising current, but as the ore pulp is charged by pipe at the center, the sands settle to the bottom and are discharged, while the slimes overflow at the periphery. The sands are then carried to the cyanide plant, where they are fed to seven additional cones and treated as above described. The slimes overflowing at the periphery are again discarded, while the sands are discharged to 4-compartment jigs of the Harz pattern, which act as classifiers. One cone feeds four jigs. The jigging is done on beds of pyrites concentrates, relatively coarse screens being employed, except in the last compartment. The stroke varies in the different compartments from 0·125 in. to about 0·5 in. The last compartment is widened out in order to accommodate the increased amount of discharge water, the overflow from which carrying the slimes is discarded. The continuous hutch discharge is taken by open launder to the revolving pipe distributors, which fill the leaching tanks, the peripheral overflow of the tanks still carrying off slimes. Lime in the form of an emulsion is added to the pulp launder which takes the jig discharge. There are 14 leaching tanks, 45 ft. in diameter, 9 ft. deep, of California red-wood, placed seven in a row, with one revolving distributor of the Butters type for each row, being moved from tank to tank by overhead track, as required. To get an even overflow at the periphery of the tank, the top of the staves are grooved to a depth of 0·5 in., and a soft pine tongue is inserted projecting from 0·5 to 0·75 in. above the top of the staves and a perfect level can be maintained by planing. It is the object to charge as much slime with the sands as possible and still leach in a reasonable time. For this purpose the adjustments are made on the jigs and distributors. The value of the pulp as it leaves the stamp mills is from $1·25 to $1·50 per ton. The amount crushed in the mills approximates 2,000 tons per day, while the cyanide mill treats about 1,200 to 1,300 tons per day. The difference, or 700 tons, is discarded as slimes which, while carrying considerable value, cannot be treated in the condition they are in. The proportion of slimes separated is about 35%. The sands are leached directly in the filling vats. Precipitation is carried on by zinc dust in five tanks 25 ft. in diameter, and 20 ft. deep, of California red-wood. The bottoms are inclined to one side, where a small sump is provided in order to drain the tank perfectly. The solutions drain from the leaching vats directly into the precipitating vats. The precipitation vats

are pumped out by duplex Prescott pumps, the solution going to filter presses made in the Homestake shops. The pulp treated by the mill is of a highly siliceous nature, often however, carrying some hornblende, the sulphides being mainly pyrite and pyrrhotite. The extraction is about 90% at a cost of 45 to 50c. per ton of material treated, probably nearer the latter figure.

The Dakota Mining & Milling Co.'s recently constructed wet crushing plant at Deadwood is of 60 tons' capacity. The ore from the Portland and Bald Mountain mines is the usual quartzite, with values very finely disseminated, which is crushed rough in a No. 2 Gates gyratory crusher, and passes to the storage bin, being fed therefrom by suspended challenge feeds to two 10-stamp batteries of 900-lb. stamps, which crush through 20-mesh woven wire screens. The mortars are double discharge, but as the ore is crushed with 0·1% cyanide solution, some of the rear discharges are closed in order to keep the amount of solution from becoming too large. With both discharges open too much solution is used. The pulp discharge is caught by a launder in front of battery, conveyed to a sump from which it is elevated by a Frenier sand pump (capacity 6,000 gal. per hour) to a distributing box with launders to convey it to the separator boxes, one of which is placed above each sand tank. These separator boxes are 5×4 ft. in cross section, and 5 ft. deep, built in two compartments, each having in the bottom a circular discharge gate, hinged and closing tight against a rubber gasket by means of a long lever. The pulp flows into one compartment, the sand settling to the bottom, while the slimes overflow at one side. When one compartment is filled with sands, the pulp is deflected to the second compartment and the first discharged into the leaching vat below. The slimes flow by launder to the first slimes settling vat where they are allowed to settle. Four pounds of lime per ton of ore are added at the batteries to aid the slimes in settling; the acidity of the ore is very slight.

The sand vats are of red cedar, 20 ft. in diameter and 5 ft. deep, arranged in four sets of two each, one below the other for double treatment of the sands. It takes 24 hours to charge a tank by means of the separator boxes. The sands are leached with a 0·2% cyanide solution, followed by 0·1% solution and wash water. They are then shoveled through the bottom discharge gates, to the second vat below and re-treated. The time of transference is 12 hours, and the cost 5c. per ton. The total time of treatment is five days, including charging, transference and discharging, this last named being done by sluicing. The extraction made on sands is 83 to 84%, of which 8% is extracted in the second treatment.

There are six slimes vats of red cedar 20 ft. in diameter and 12 ft. deep, and after settling out the slimes from the solution in the first slimes vat the solution is drawn off as close as possible by siphoning, and is passed through the zinc boxes, thence to the barren solution sump tank. Fresh weak solution is added to the settled slimes, and the slimes mixture is then pumped by a sand pump to a second slimes vat, where the operation is repeated as above. The slimes are re-pumped four times, the last time wash water being added instead of weak solution; they are discharged by sluicing after the last settling. An extraction of 88% is made on the slimes, although only about 80% is saved,

the balance going out with the slimes, which retain about 100% of moisture. Only one wash water is used, as otherwise too great a bulk of solution is accumulated. The total time consumed in treating a vat of slimes is six days. Four 10-compartment zinc boxes are used to precipitate the solution.

The cyanide plant of the Wasp No. 2 Mining Co., on Yellow Creek, near Kirk, is a dry, coarse crushing plant of 90 tons' capacity per day. The ore is quartzite, the gold being on the cleavage planes, and in the seams and cracks so that coarse crushing only is necessary to make it available for solution. The value varies from $3 to $12 per ton, the main bulk averaging about $4. It is mined very cheaply (85 to 90c.) by open-cut mining. The mill is built in terraces on a very steep hillside, and the ore is moved through almost entirely by gravity. It is hauled from the mine 750 ft. distant in trains of four cars, and charged into the main bin from which it passes to a No. 2 D. Gates crusher over a 4×8-ft. grizzly having 1·5-in. spaces between bars. The undersize and the crushed ore from the Gates go to the storage bin, from which it is fed by Tulloch feeders into one set of coarse Gates rolls 14×24 in., 80 revolutions per minute. The rolls discharge to a stationary inclined 2-mesh screen 7×1 ft., the oversize from which passes through the finishing rolls 14×24 in., operated at 100 r.p.m., and meets the undersize, the combined product being elevated by a bucket elevator to the shaking finishing screen, situated on a level with the coarse rolls. This screen is an inclined shaking 2·5-mesh screen, 16×2 ft., the lower half being stationary. Nearly all of the finished product passes a 6-mesh screen, the oversize from which being returned by gravity to the finishing rolls. The ore is charged from the finished product bin into the four leaching tanks of Oregon fir; each tank is 16 ft. diameter, 7 ft. deep and of 55 tons' capacity. For this purpose a 16-in. belt conveyor is used at a speed of 600 ft. per minute. A large 100-ton tank has recently been added, which gives the mill the capacity mentioned above. Tanks are charged in from 2 to 2·5 hours, the cyanide solution being added after the tank is about one-half filled. The strength of the strong solution is 6 lb. cyanide per ton of solution. About 15 tons of strong solution are run on and usually allowed to stand 3 to 4 hours, then it is drained, a weak solution being added at top to replace it. After this complete replacement it is allowed to stand a short time and then circulated for the balance of the leaching. The weak solution contains from 2·5 to 3 lb. cyanide per ton. About 50 tons of weak solution are used, followed by from 6 to 9 tons of wash water. To neutralize the acidity of the ore and give a protective alkalinity, 6 lb. of lime per ton are added before the ore is dumped into the first bins. The cost of cyaniding is from 85 to 90c. per ton. The precipitation is accomplished by zinc threads in specially constructed barrels, and very good results are obtained, the tailings solution having a value of from 4 to 10c. per ton. The extraction made is from 80 to 90% of the values, and the consumption of the cyanide amounts to about 0·5 lb. per ton of ore. The precipitates are treated by the usual sulphuric acid method. Zinc dust precipitation in the tanks, pumping the resultant mixture through filter presses, was tried at the mill, but discarded on account of the difficulty in the clean-up.

The new dry crushing cyanide mill of the Imperial Gold Mining & Milling Co., in course of erection at Deadwood, has facilities for roasting the heavier blue ores. The mill is modeled after the Florence pattern, and is built on the level, with the crushing, roasting and leaching departments inclosed in separate adjoining buildings. The entire product is handled automatically by belt conveyors and elevators. The crushing is done by a Blake crusher and Davies rolls, and the screening mostly by rotary screens. The sulphide ores are to be roasted in a Holthoff-Wethey double-hearth furnace, the lower hearth being used for cooling. Ample provision is made for dust collection. The mill has an automatic Vezin sampler, which samples all material passing through the mill. The four leaching tanks are of 0·1875-in. steel, 35 ft. diameter and 6 ft. deep, and the other tanks also are of steel, including the zinc boxes. The following costs of milling are approximately correct, and but little variation from these figures will be found in modern practice. The cost of the wet crushing process per ton is $2, or a little less. The cost of coarse crushing on lime ores by the Spearfish Co. before its plant was destroyed was from 75 to 80c. per ton. The cost of fine dry crushing and cyaniding has not yet been demonstrated. The old Golden Gate mill was too small and of too old a type to show modern practice, but as demonstrated there it amounted to from $4·50 to $5 per ton when treating a very limited amount. The actual cost, under modern conditions, is undoubtedly about $2 per ton.

The following list comprises cyanide mills both operative and inoperative, together with those in course of erection January 1, 1902:—

Mills in operation.—1. Homestake, at Lead, S. Dak., 1,200 tons, stamp mill tailings.

2. Portland, at Gayville, S. Dak., 60 tons.

3. Wasp No. 2 Mining Co., near Kirk, S. Dak, 90 tons.

4. Cleopatra Mining & Milling Co., on Squaw Creek, 100 tons.

5. Dakota Mining & Milling Co., in Deadwood, 60 tons.

Mills not in operation.—1. Golden Gate, closed since September, 1901.

2. Shawmut Gold Mining & Milling Co., Black-tail Gulch, near Central City, 30 tons.

3. Annie Creek cyanide mill, Annie Creek, 100 tons.

4. Clevenger plant, Rapid City, 30 tons, chlorination tailings.

Mills in the course of erection.—1. Imperial Gold Mining & Milling Co., Deadwood, 100 tons.

2. Golden Reward Mining Co., Deadwood, 200 tons.

3. Spearfish Gold Mining & Milling Co., Preston, 250 tons; this mill takes the place of the one recently destroyed by fire, which was on the active list before its destruction.

4. Deadwood Standard Mining Co., Preston, 200 tons.

5. Homestake Central cyanide mill, at Gayville, 600 tons, tailings.

6. Little Blue Mining Co., Alder Creek, near Kirk, 50 tons.

There are several mills projected which will probably be built in the spring. The mills named under the heading "In course of erection," will be completed in two to five months from date unless delayed. Under the head of "Mills not

in operation," the Golden Gate mill will be probably permanently closed, unless it is more modernized. The Shawmut may in the near future increase its capacity. There are rumors of the Annie Creek mill restarting in the near future. The Clevenger plant, at Rapid City, has exhausted the supply of tailings from the chlorination mill, and is being dismantled.

Aside from the larger plants above stated, there have been four plants along Whitewood Creek operating on Homestake tailings this summer. At the old Dakota plant (10 tons), Central City, an experimental plant, has been at work at intervals. The small mill at Gayville, known as the Parker, Gibbs & Cook mill, has been at work part of the time. The Deadbroke Mining Co.'s combined stamp and cyanide mill in Blacktail Gulch, has also been experimenting. There is a plant at Mystic, employing a secret cyanide process which has not as yet treated ore on a commercial scale. Aside from the above mentioned plants, there are two or three smaller ones not operative at the end of the year.

Idaho.—In this State cyaniding seems to have made but little progress, for, with the exception of the mill of the De La Mar Mining Co., there are only a few small plants in operation.

Montana.—Many new plants have been erected during the year, some being of considerable size, notably that of the Empire Co., near Marysville, with a daily capacity of 500 tons, the Montana Mining Co.'s plant in Deer Lodge County having a capacity of 400 tons per day, and several others, varying from 100 to 200 tons daily. The industry is confined principally to the following counties: Fergus, Deer Lodge, Lewis and Clarke, and Madison.

The Fergus County ores are well adapted to cyaniding and when crushed so as to pass a 0·25-in. round hole are said to yield a 90% extraction. A large proportion of the ore assays only about $3 per ton. In many of the mills the method followed is crushing by stamps, amalgamating, and cyaniding the tailings. In others the ore is crushed in rolls and then treated directly in the leaching tanks. In some cases the tailings are so slimy that they cannot be treated by percolation, therefore agitation and decantation have been employed with good results.

Nevada.—A few new mills have been built in this State during the year, the largest being that of the Chainman Co., at Ely, with an estimated capacity of 300 tons per day. This plant was described in the *Engineering and Mining Journal,* December 7, 1901. The Ely Mining & Milling Co. also has a new 50-ton plant which went into operation last spring.

At Tuscarora the Dexter Gold Mining Co. treated 100 tons per day, and near the same place the Bull Run Mining Co. has put in a new plant. The Cuyahoga Co., of Lyon County, also has completed a new mill. The process in use differs at the various mills.

At the Dexter plant, treating slimy ores, the method, as described by William Magenau, is quite different from that at the Chainman. The ore is crushed with stamps and amalgamated, the tailings going to settling tanks equipped with Butters and Mein distributors. The settlers catch 51% of the material run into them, the overflow carrying the slimes being run into ponds and settled. As soon as one pond is full the stream is turned into another and the former

allowed to dry for several months. The climate is so dry that in this time the upper few feet of the material become well baked. It is then put into cars by means of wheeled scrapers and carried to the leaching tanks to be mixed with the sands. As soon as a settler is full of sands they are shoveled into cars through a hole in the bottom and carried to the leaching tanks, where they are mixed with the dried slimes in the proportion of one car of sands to one of slimes. The mixture is leached continuously for from three to five days with a 0·2% solution of cyanide, the solution running in at the top as fast as it runs out at the bottom. Before discharging, a single water wash is given after the charge has been allowed to drain for several hours, or until no more solution runs off. The cyanide solutions go directly to the zinc boxes. The sands average $1·57 gold and $1·70 silver and the slimes $3·19 gold and $5·03 silver. The extraction is 66·8% of the gold and 37·7% of the silver. At the Ely mine a dry crushing process is used; the ore after passing through a crusher is dried in a rotary furnace and then crushed to 20-mesh size in rolls, from which it goes to the leaching tanks. The ore leaches easily and the extraction is 80%.

New Mexico.—The Cochiti Gold Mining Co., of Bland, has in successful operation a method of treating the dust from their dry crushing mill, which has been described by Charles S. Hurter in the *Engineering and Mining Journal,* January 19, 1901. Here 98% of the dust will pass a 100-mesh screen. The process used is agitating and settling, the agitation being effected by steam and compressed air, the latter being under 60-lb. pressure. The steam is used to heat the charge, as it was found that the air on expanding cooled it too much. The mixture of air and steam is admitted through 1-in. horizontal iron pipes in the bottom of the tank. The pipes have 0·0625-in. holes in the under side for the escape of the air and steam. In 24 hours 94% of the total values are in solution, using a solution of cyanide of 3 lb. per ton, but only 80% is recovered, due to the solution going to waste in the slimes. To neutralize the acidity of the ore and to aid the settling of the slimes, lime is suspended in a wire basket in the upper part of the tank. The cost of treatment is given as $1 per ton.

Utah.—In the Mercur district cyaniding has been active and a large quantity of ore has been treated. The tailings at Manning are being treated and satisfactory results are reported. The Annie Laurie Co., of Piute County, completed a large new plant this year that has been running successfully. In addition to the plants above mentioned a few small ones have been built.

Washington.—Cyaniding in this State has been confined principally to the mill of the Republic Power & Cyaniding Co. Although this mill was closed in July, 1901, a description of the plant and process will be interesting as these ores were for some time a puzzle to metallurgists. Mr. D. C. Jackling has kindly furnished the following details of the process:—

The new plant, started in October, 1900, had a rough-crushing capacity of 400 tons and a milling capacity of 200 tons in 24 hours. The ore was dry ground to 60-mesh, roasted "dead," cyanided by direct percolation, and precipitated with zinc dust. The ore is quartzose, dense, hard and tough, often with banded white to black layers, and the numerous fractures usually coated with a soft

white substance like amorphous silica. As it comes from the mine it contains SiO_2, about 90%; $CaCO_3$, up to 5%, averaging 1·5%; S, up to 1%, averaging 0·5%; Cu, up to 0·1%, averaging 0·01%; Pb, Zn, As, Sb, sometimes in traces and Te none. The proportion of silver to gold in the ores treated was about 3·2 oz. silver to 1 oz. gold. The average for the district is about 5 to 1. Previous to the present plant several thousand tons of ore carrying 3 to 4 oz. gold, were treated by the Pelatin-Clerici process. It was ground wet in ball mills to from 80- to 120-mesh but under the most favorable conditions less than 90% of the gold dissolved. On 1·5 oz.-ore, the extraction decreased to 70%. These ores show scarcely any free gold even under the microscope and it is hard to account for unless, as suggested by Chatard and Whitehead, the gold particles are enveloped in a film of hydrated iron and aluminum oxides.

Calcination of the ore removed many of the difficulties, the only objection being a lessened extraction of silver. Coarser crushing can then be used and the roasted product leached by percolation in deep tanks.

The ore is put through a No. 5 Gates crusher, then through a Gates fine crusher (style H.), then through 15×36-in. Gates rolls. The crushed ore is sized here to about 0·5-in. before drying. The sampled ore goes to the main storage bin above the fine crushing department from which it is fed automatically to the cylindrical dryers of which there are two, each 26 ft.×60 in. The fine crushing department contains besides the dryers two sets of 15×36-in. and two sets of 15×26-in. Gates rolls, six 30-in. Griffin mills, six 8-ft. Jeffrey Columbian separators, etc. The rolls are in two series of a 36-in. followed by a 26-in., each series being served by one dryer and serving in turn three Griffin mills. These mills have 40-mesh screens set at an angle of about 40° and deliver a product 96% of which will pass a 60-mesh screen. The drying, grinding, screening and accessory machinery in this department requires about 1·25 H.P. per ton finished ore. Using rolled steel shells of best quality on the rolls and rings and dies of the same material in the Griffin mills the steel consumed per ton ore is about 1·25 lb. Dust chambers connected by large exhausters with the chief sources of dust are provided.

The following table gives the average of samples taken daily of finished mill pulp:—

Remaining on 40 mesh	1%	Through 120 mesh—remaining on 150	10·50%
Through 40 mesh—remaining on 50	1%	Through 150 mesh—remaining on 200	8%
Through 50 mesh—remaining on 60	2·50%	Through 200	57%
Through 60 mesh—remaining on 80	7%	Total	100%
Through 80 mesh—remaining on 100	8%		
Through 100 mesh—remaining on 120	10%		

The finished pulp passes to the roasting furnaces, of which there are three of the straight line type with hearths 100×12 ft. The tops of these furnaces are covered with heavy corrugated iron and are used as a cooling floor for the roasted ore, along which it is moved by the returning rabbles, and during the last 25 ft. is sprayed with water. To yield good results the ore requires a surprisingly high temperature and long exposure to the heat and an almost complete expulsion of the sulphur.

The leaching plant contains 16 steel leaching tanks 22 ft. square by 6·5 ft.

deep, each of 110 tons' capacity. Three steel solution and standardizing tanks 14 ft. diameter by 10 ft. deep are also located in this section on a platform 12 ft. above the tops of the leaching tanks.

In the precipitating department are two precipitating tanks 10 ft. diameter by 8 ft. deep, two gold-solution tanks 14 ft. diameter by 10 ft. deep, one sump tank 24 ft. diameter by 5 ft. deep, all tanks being of steel. Solutions are handled by two Root rotary pumps. The slimes from the zinc dust precipitation are collected in four 24×36-in. Johnson filter presses. Vacuum is supplied for the leaching tanks by an 8×10-in. triplex power pump. The first solution 0·5% KCy is run in from the bottom of the charge until the whole is thoroughly saturated, percolation is then started and proceeds by gravity alone for 72 hours, after which vacuum is used. About 20 tons of this solution, besides that necessary to saturate the charge, are run in requiring from 36 to 48 hours. Weak solution, 0·3 KCy, is then run in until tests show the extraction to be nearly finished. About 40 or 50 tons of this are used during a period of from 72 to 84 hours. Wash water to the amount of 20 or 25 tons is now used and requires from 48 to 60 hours to drain. The total time required for loading, leaching and discharging a tank is almost nine days, and the total solution and wash water used, exclusive of that used to saturate the charge, is about 85% of the weight of the ore. The tanks are discharged through openings in the bottom. Filling and unloading costs about 11c. per ton. All solutions from the leaching tanks, including wash water, run into the same gold-solution tank and after precipitation the mixed solution becomes the weak one for succeeding tanks, strong solution being made up from it by addition of cyanide in lumps. Sufficient caustic soda is used to keep the alkalinity of the solutions at about 0·3%. When no lime is present the amount used is about 0·8 lb. per ton ore. The consumption of cyanide averages 1·18 lb. per ton ore. On 0·75 oz.-ore, the gold extraction by bullion produced was, 91·3%, and silver 15·6%. Precipitation is effected by zinc dust, 20 tons of solution at a time having the necessary amount sifted in while the solution is being agitated by compressed air. The amount required is about 0·95 lb. per ton ore, or 1·25 lb. per oz. of gold. If the alkalinity of the solution is kept at the proper standard the precipitation is rapid and complete, except in the presence of appreciable amounts of copper, when it becomes difficult. The precipitates and slimes are collected in filter presses and refined in the usual way by treatment with sulphuric acid, etc. The resulting bullion is about ·900 fine in gold and silver.

CYANIDE PATENT LITIGATION IN 1901.—A case of considerable interest regarding the use of zinc dust or fume as a precipitant of gold and silver from cyanide solutions was recently decided by the United States District Court for Idaho. The suit was brought by Capt. J. R. De La Mar against the De Lamar Mining Co. to prevent the latter using zinc dust as a precipitant, and claiming that such use was an infringement of United States Patent No. 607,719, of March 9, 1896, covering certain improvements in the cyanide process. The court decided against the plaintiff and held that the patent was anticipated by prior publications and patents. It is supposed that Captain De La Mar will carry the case up to a higher court for final decision.

The claims of this patent are as follows:—

"Claim 1. The process of extracting precious metals from cyanide solutions, which consists in treating said solutions with zinc dust, to wit, the herein described material composed of zinc and zinc oxide, in a state of agitation, substantially as described.

"Claim 2. In the process of extracting precious metals from cyanide solutions the use as a precipitating reagent of a definite quantity of zinc dust in a state of agitation, the quantity of said zinc dust being supplied in only a sufficient quantity to thoroughly precipitate the contained metals, substantially as described.

"Claim 3. The process for extracting and recovering precious metals from their ores and which consists essentially of the following steps: First, subjecting the ore in a powdered state to the action of an aqueous solution of a cyanide; second, supplying to the solution charged with the precious metals that quantity of zinc dust determined to be exactly sufficient to precipitate said metals; third, agitating said solution and said zinc dust until said metals are precipitated, and said zinc dust is absorbed; fourth, recovering the precious metals from the valuable precipitate of the preceding steps by filtration or other process, substantially as described."

With regard to the use of zinc dust prior to the application for the patent, H. L. Sulman,[1] after speaking of the different methods of precipitation in use and describing the requirements demanded of a metallic precipitant, goes on to say that all the conditions are fulfilled "by the product known as zinc fume. * * * It is a commercial by-product * * * being the condensed metallic vapor in a state of extreme division." "It is an impalpable metallic flour and is seen under the microscope to consist of spheres more or less coated with oxide." This oxide, he says, retards somewhat the precipitating action and he recommends treating the product with dilute ammonia or some similar solvent of zinc oxide, thus leaving the zinc clean. "A small portion of this preparation agitated with a very dilute solution of auro-potassic cyanide permeates the whole volume of liquor rendering it slightly and uniformly cloudy * * * and almost immediately determines the precipitation of the gold." "I have treated considerable volumes of gold solutions of varying strengths of cyanide and with an expenditure of zinc fume never exceeding 0·5 lb. per ton of ore have obtained precipitates which seldom contained below 97 to 98% of the gold originally present in the liquor." "When the solutions are rich in metal (or over 0·3 oz. per ton) the addition of zinc fume of from three to four times the weight of gold present has been sufficient to completely precipitate the latter. Very dilute solutions strangely enough require rather more than this."

It will be seen from the quotations given that every claim of the Waldstein or the De La Mar patent is fully and clearly anticipated by the process described by Sulman. The only difference between the two is in Sulman's treatment of the zinc dust with an ammoniacal solution so as to remove the oxide as he says the presence of the latter (the oxide) renders the action of the untreated product *somewhat* slow as a gold precipitant. From this it is plainly evident that he knew

[1] *Institution of Mining and Metallurgy*, London, Feb. 20, 1895.

that zinc dust in its untreated state would precipitate gold, but not quite so rapidly as when freed from the adhering oxide.

His United States Patent No. 576,173, filed February 25, 1895, also clearly shows that he did not consider it possible to patent the use of zinc dust alone as a precipitant, for all he attempts to cover in his patent is the process for removing the zinc oxide so as to make the zinc more active, and a special form of apparatus in which to make the precipitation.

Aside from Sulman's work it does not seem possible that such a patent could be valid, for even Dr. Waldstein must admit that it is the zinc of the zinc dust that causes the precipitation and not the oxide. Such being the case, in what way does it differ from the ordinary zinc precipitation, except that the zinc is in a more finely divided state, a condition which was well known to be favorable to precipitation?

Australia.—According to Mr. A. G. Charleton[1] cyaniding at Kalgoorlie is being carried on very successfully in spite of the slimy nature of the ore, due to the presence of silicates of magnesium and aluminum, and hydrated oxides of iron which form over 40% of the lode stuff. The practice varies considerably at the different mills. At the Lake View South the ore is crushed and amalgamated as usual, then goes through grinding pans and from there to Frue vanners, which yield concentrates containing 2 to 3 oz. gold per ton. These concentrates are cyanided at a cost, said to be 8s. 9d. per ton. The Associated mill treats the oxidized ore by dry crushing and cyaniding. The ore is first passed through crushers, then into a sizing trommel which separates the fines from the coarse rock. The fines are raised by a bucket elevator into a bin and the coarse ore goes to Krupp ball mills, the product from which is then raised in an elevator and joins the fines. The ore in the bins is discharged through canvas spouts into steel trucks holding about 1 ton and having W-shaped bottoms, the sides forming flap doors. Four or five of these trucks placed end to end are set on a carriage running on rails alongside the vats and which is moved back and forth by means of an endless rope controlled by a lever shifting the driving belt from a fast to a loose pulley. The vats hold 160 tons each, and it is claimed that this arrangement fills them more evenly and no trimming is required. Two men fill a vat in from 8 to 10 hours. The charge is kept under cyanide treatment for 10 days. The residues are discharged through bottom doors into trucks below. The cost of cyaniding is 5s. 6d. per ton. The Brown Hill mill also uses dry crushing in Krupp mills but the sizing is done by air separators and the coarse classified products are cyanided separately, in steel vats, and the slimes are treated by agitation and filter pressing. At this mill bromo-cyanide is used instead of potassium cyanide alone. Experience has shown that in some of the mills the slimes are of too low value to pay for treatment, while at others they are of comparatively high grade. This has led to two different methods of treatment. At the Great Boulder the dry tailings from the settling ponds are carried to the cyanide plant and both sands and slimes, after being broken up in a disintegrator are run into a sump, then pumped into a vat with radial arms and agitated in these vats with cyanide. When the gold is dissolved

[1] *Engineering Magazine*, June, 1901.

the pulp is filter pressed and the solution passed through the zinc boxes. The cost of this treatment in 1899 was 11s. 6d. per ton. The tailings after treatment contain 39 grains gold per ton and the loss in cyanide was 2·2 lb. At the Boulder Main Reef and North Boulder the sands are separated in one pond and the slimes in another. The sands only are treated, as the slimes are said to be worthless. The Lake View treats battery tailings containing about 80% slimes by first passing through a spitzkasten, from which the sands are elevated by a tailings wheel to six collecting tanks fitted with Butters & Mein's distributors. The sands which settle to the bottom still contain 40 to 50% of 100-mesh slimes. These sands are trucked to leaching vats in another building and cyanided for 10 days. The slimes from the distributors together with those from the spitzkasten are settled in tanks and then forced by compressed air into filter presses through which the cyanide leaching solution is pumped, and the residues finally washed with water. The process takes about 4 hours. The Ivanhoe uses still another plan. The battery tailings are first lifted to spitzlutten which separate the coarse sands. These go to grinding and amalgamating pans, after which they pass through spitzkasten, the overflowing pulp from which, together with that from the spitzlutten, goes to the cyanide vats. The Ivanhoe plant consists of sixteen 80-ton vats placed in two series one above the other, the lower vats being 5 ft. below the upper ones. The upper vats are provided with Butters & Mein's distributors, and are used both for settling and leaching. The slimes which overflow go to the slimes plant. The sands after the vats are filled to the required depth are drained and then leached for four days in the upper series, then dropped through bottom discharge doors to the lower series and again leached for four days. This double treatment is said to shorten the time required for extraction by two days. The capacity of the sand plant is 120 to 140 tons per day, and the cost of treatment, including grinding and amalgamation is said to be 5s. 6d. per ton. The slimes from the upper series of vats are run into settlers and after settling are passed into agitators with cyanide solution and agitated for 8 hours. The pulp is then forced through Dehne filter presses and washed with spent liquors. The capacity of this slimes plant is 150 tons per day and the extraction is said to be 80 to 90%. The New Zealand Government has decided to keep in force the cyanide patents which they bought four years ago, until the royalties received shall equal the expenditure. So far the royalties received, £4,253, are equivalent to 42·5% of the cost.

F. B. Stevens[3] gives the following description of his experience in treating acid tailings at the Wemmer Gold Mining Co., of Johannesburg. The tailings contained large quantities of ferrous and ferric sulphates as well as free sulphuric acid. The treatment first used was to give a water wash, then add lime and wash with caustic soda, and follow with cyanide. A large discrepancy between the actual extraction and that shown by assay had always existed, and it was suggested that the loss took place during the washing and was caused by the cyanide left in the vat from the previous treatment. It was then decided to wash the ore in a separate vat. The process finally adopted was as follows: The ore was washed with water for 12 hours then transferred

[3] *New Zealand Mines Record*, Jan. 16, 1901.

to another vat and mixed with lime and given a wash with caustic soda. To prevent iron hydrate from getting into the zinc boxes it was found advisable to fill the vat to a depth of 3 in. with sand and then to spread over it a layer of lime. This was found to catch a very considerable amount of oxide of iron. So soon as the washes began to come off distinctly alkaline the cyanide treatment was begun. By the above plan it was found possible to work these tailings successfully although the loss in cyanide was always above the average.

Mexico.—Messrs. Tays and Scheirtz[4] described their method of treating clay slimes at the Guadalupe mine of the Anglo-Mexican Mining Co. About 80% of these slimes were pure clay finer than 400-mesh, the balance being sand slimes passing 200-mesh. The gold value was about $13 per ton. The method adopted was to agitate for 5 hours with 0·15% KCy in the proportion of 2·6 tons solution to 1 ton moist slimes, adding lime during the last part of the agitation, then settle for 7 hours and decant. After the first decantation water or weak cyanide was added in amount equal to that just decanted and the mixture agitated for one hour, then settled for six hours. The solution from the settling tanks then passed to a settling box, a long trough much wider at the discharge end than at the inlet. The clear solution from this passed to the gold solution tanks and from them to the zinc boxes. The extraction of gold was about 78%. Loss in cyanide 7 lb. per ton.

Cyaniding Cupriferous Ores.—According to Louis Janin, Jr.,[5] the pyritic ores of the Lydenburg (Transvaal) district present some interesting difficulties. These ores contain quartz, iron oxides, dolomite and small quantities of manganese, copper, bismuth and silver. The bismuth causes no difficulty, and the manganese dissolves only when an insufficient amount of lime is used. Not over 10% of the silver is recovered. The average amount of copper is about 0·4% and occurs as oxide, carbonate, in iron pyrites, and occasionally as copper sulphides and metallic copper. The latter is almost all caught on the amalgamating plates, and of the rest only a small amount is dissolved in the potassium cyanide. Unsuccessful attempts were made to dissolve out the copper with acid. The only method which has given satisfactory results depends on the property of potassium cupro-cyanide[6] to dissolve a small quantity of copper in the form of subcyanide, which is then precipitated by the Siemens-Halske process. A solution obtained in the ordinary course of practice containing cupro-cyanide but no free cyanide is employed. It was found that the tanks should not exceed 3 ft. in depth, otherwise the free cyanide would be exhausted. About 5 lb. of lime per ton is added to the sands and 15 lb. to the slimes; an alkaline wash is then used followed by one with a solution of about 0·07% KCN. In passing through the ore the free cyanide dissolves some of the copper as cupro-cyanide (?) which then dissolves more of the copper as subcyanide. "These subcyanides are converted by free cyanide into the normal cupro-cyanides. After the loss has been determined the strength of the following solution is roughly estimated, this will be from 0·1 to 0·2% free cyanide. In order to avoid loss of cyanide as much as possible,

[4] Paper read before the Mexican Meeting of the American Institute of Mining Engineers, November, 1901.
[5] *Engineering and Mining Journal*, Aug. 17, 1901.
[6] More probably cuproso-cupric cyanide.—J. S. C. W.

drawing off the solution is suspended when its strength reaches the normal point—about 0·05%. This strength is naturally determined by practice." After the gold is dissolved a dilute solution is employed as in the ordinary process to remove all the gold. A small quantity of copper was found not to interfere with the precipitation of gold on zinc shavings, but when the point reaches 0·01 to 0·02% it causes a great deal of trouble, enveloping the zinc and preventing precipitation. For several years a system of intermittent washing of the zinc boxes with an excess of cyanide was used, followed by maintaining the normal strength of the solution by the addition of cyanide in a thin stream at the head of the zinc boxes, and frequently changing the charge of the compartments. When the zinc-lead couple became known it was introduced, and the precipitation of the copper as well as the gold was increased by it. To assure regular precipitation the free cyanide in the solution must be maintained between 0·03 to 0·12%, depending on the amount of copper present. Precipitated gold has a tendency to dissolve in these solutions from cupriferous ores unless the boxes are regularly soaked with cyanide as before mentioned. For example, a solution containing only 4 dwt. gold and 0·05% free cyanide has left the boxes when a cyanide was not employed, carrying 30 dwt. gold. Weak solutions were found to precipitate more copper than strong ones. By using the Siemens-Halske process these difficulties are avoided—the cyanide is regenerated and the gold and copper are precipitated as a hard adherent coating. On the anodes a hard crust of iron cupro-cyanide (?) is formed that causes the current to flow unequally between the plates, causing a tendency to short circuit. This may be prevented to some extent by hanging the anodes in cloth sacks, using as weak a current as possible and moving the lead strips daily. It is also advisable that connection between the sheet iron anode and the copper conductor be made by fine iron wire that will burn out if the current becomes too strong and call attention to the formation of a short circuit.

Cyanide Solutions containing Copper.—W. H. Virgoe[7] gives his experience in the testing of cyanide solutions containing copper both when using potassium iodide as an indicator and when silver nitrate alone was used. His conclusion is that when copper salts are present the use of silver nitrate alone is inaccurate, such solutions apparently showing free cyanide when none is present. When using the iodide as an indicator the results appear to be reliable. As an example he says "a solution containing 0·3% Cu and titrating 0·52% with silver nitrate alone may titrate 0·13% potassium cyanide correctly if potassium iodide be used." He finds that in titrating pure solutions of potassium cyanide the amount of the indicator used makes no difference, but in strongly alkaline solutions or in those containing copper it affects the results very materially. The use of two or three drops of a 2% solution of potassium iodide is recommended as giving correct results except in cases where much free alkali is present when the results are apt to be too high. Cyanide solutions containing 0·3% or over of copper yield very poor extraction and it becomes necessary to purify them. This he says can easily be done by the lead-zinc couple as practiced at the Creston-Colorado plant at Minas Prietas, Sonora, Mexico. The details are those given him by Mr. Higgins,

[7] Paper read before the Institute of Mining and Metallurgy, December, 1901.

the superintendent. The plant has a capacity of 250 tons daily. "The solution coming from the tanks titrates about 0·23% KCN and flows first through fourteen ordinary zinc launders 18×2·5×2·5 ft. in size—where the fine product is collected; secondly, from these launders the solution is taken through six other launders with zinc-lead in each compartment. I use 1·5 lb. lead acetate to 15 lb. zinc shavings; in other words, about 160 lb. of lead acetate for 7,500 tons ore." To form the lead-zinc couple the compartments in the zinc boxes used for this part of the process are filled with condensed water from the boiler and 1·5 lb. of lead acetate is dissolved in each. After solution, 15 lb. of zinc shavings are pressed into each compartment and allowed to stand for half an hour or more. The solution after passing through the plain zinc boxes where most of the gold and silver is precipitated, then flows through the lead-zinc boxes prepared in the way just described which remove a large proportion of the copper. Solutions that previously contained from 3 to 4 lb. copper per ton are by this treatment reduced to 1·25 lb. Cu, which amount causes no trouble. The product from these boxes containing about $2 per lb. in gold and silver and 45% Cu is sent to the smelters. Mr. Virgoe suggests as another possible method of purifying the solution precipitating the copper with zinc dust and then removing the zinc by treatment with an alkaline sulphide. He gives the following method for the determination of gold and silver in cyanide solutions: To 1,000 c.c. of the solution, add an excess of copper sulphate and acidify with hydrochloric, nitric or sulphuric acid. The precipitate, which is white and flocculent contains all the gold and silver and the blue or green color of the filtrate indicates that an excess of the copper sulphate has been added. The precipitate is washed, dried and placed in a scorifier with lead. The results are accurate and the whole operation can be done in an hour and a half.

The Bromo-Cyanide Process has been adopted by several of the Australian mining companies, among them being the Lake View, the Hannan's Star and Brown Hill mills. The results are said to be very satisfactory. A test on 653 tons of sulphide ore at the Brown Hill mill yielding an extraction of 95·7% of the gold, and other results as high as 97·6% are said to have been obtained. The consumption of cyanogen bromide varied from 0·5 to 1 lb. per ton ore. These ores are sulpho-tellurides of very high grade, running from 1·51 to 3·5 oz. gold. The process is generally known there as the "Diehl." It is claimed that the combination of the two cyanides is capable of dissolving telluride of gold, whereas in simple cyanide it is insoluble. Also that no oxygen is necessary in the process and consequently it is especially well adapted to the treatment of sulphides such as concentrates, etc. That these claims are well founded seems to be established by the success obtained in Australia and with the mispickel ores of Deloro, Canada, which are well known to be very refractory. Mr. Wright in a paper read before the Canadian Mining Institute, 1901, gives the following particulars of the process as used there: The wet concentrates from the mill consist principally of mispickel, some iron pyrites with small amounts of copper and from 15 to 20% of quartz sands. These are dumped directly into the vats to a depth of 3 ft. (equivalent to about 40 tons) and a little lime added. After leveling, the charge is sampled by a 2-in. augur, 20 to 30 holes being bored to

the bottom of the charge. A short water wash is then given and as soon as the water has disappeared from the top of the ore the mixture of potassium cyanide and cyanogen bromide is run on to an amount approximately one-third the weight of the ore. The wash water still draining out is run through zinc boxes until on testing the solution with ferric chloride a distinct blue color is obtained. When this shows the solution is switched to the strong solution tank. Constant slow percolation has been found to yield the best results, so the solution after it runs through is brought up to strength and continued in circulation for 24 hours. By this time 60 to 70% of the gold has been extracted and it has been found advisable at this point to drain the charge and then turn it over by shoveling so as to break up and mix any lumps that may be present. The cyanide solution is again run on and the leaching continued until assays show the extraction to be complete. A weak cyanide wash is then given, followed by one of water only. The gold is precipitated by zinc fume, a Sulman's cone being used for the purpose. Ninety-nine per cent. of the gold in the solution is reported to have been obtained. The consumption per ton of concentrate is: potassium cyanide, 2 lb.; cyanogen bromide, 0·5 lb.; zinc fume 0·19 lb.; time of treatment, 80 to 100 hours; extraction of gold, 87 to 94%. The Gold Ore Treatment Co., which controls the patents for this process, gives the price of cyanogen bromide as 2s. 6d. to 3s. per pound, but expects shortly to be able to reduce the price. A factory is now being built in Australia to supply the demand in that country.

Testing Cyanide Solutions containing Zinc.—L. W. Green[8] gives a method based on the following:—

(1) Potassium ferrocyanide is neutral to phenol-phthalein.

(2) One cubic centimeter of N/10 potassium ferrocyanide precipitates 0·75 c.c. N/10 zinc solution from dilute neutral solutions. (Sufficiently exact for technical purposes.)

(3) When a dilute neutral zinc solution is precipitated by excess of sodium carbonate, the excess of alkali being afterward neutralized with N/10 acid using phenol-phthalein as indicator, a precipitate of basic carbonate of almost constant composition is obtained, *viz.*, $3Zn(OH)_2$, $2ZnCO_3$.

(4) Zinc hydrate or carbonate treated with an excess of potassium ferrocyanide yields zinc ferrocyanide and potassium hydrate or carbonate as follows:—

$$6Zn(OH)_2+4K_4FeCy_6=K_4FeCy_6,3Zn_2FeCy_6+12KOH, \text{ or}$$
$$6ZnCO_3+4K_4FeCy_6=K_4FeCy_6,3Zn_2FeCy_6+6K_2CO_3.$$

The above reactions do not take place immediately and are only complete by neutralizing the alkali as formed.

(*A*) Total cyanide.—Add excess of sodium hydrate and a drop or two of potassium iodide and titrate with silver nitrate till a distinct permanent *yellow* cloudiness is formed. Result equals total cyanide which we will designate by T c.c.

(*B*) Hydrates of the alkalies and alkaline earths plus half the monocarbonate. (*Protective alkali.*)—Add excess of potassium ferrocyanide, then sufficient silver nitrate (as shown by *A*) to precipitate all of the cyanide present. A slight excess

[8] Paper read before the Institute of Mining and Metallurgy, Oct. 17, 1901.

does not matter. The zinc is all precipitated as ferrocyanide and the alkali hydrates and carbonates are left in solution. Phenol-phthalein is then added and the solution titrated with N/10 nitric acid. Result equals the protective alkali (p).

(*C*) Estimation of the alkaline hydrate.—Add excess of barium chloride, sufficient to precipitate all the sulphates and carbonates, and then proceed as in the last test. Result equals the alkaline hydrates (h). In case no hydrates are found bicarbonates may exist in the solution. These can be determined by adding a known quantity of standard alkali and repeating the above test.

(*D*) Determination of total cyanides, ferrocyanides, sulphocyanides, chlorides, etc.—Add sufficient acid (as shown by *B*) to neutralize the alkali present, then a drop of potassium chromate and titrate with silver nitrate until a faint *permanent* red color appears.

(*E*) Ferrocyanides.—Add about 10 c.c. N/10 sodium carbonate, then sufficient silver nitrate to precipitate all the cyanide (T c.c.) and shake well. The ferrocyanide present will all be precipitated by the zinc in the solution, and any excess of zinc will be thrown down as basic carbonate, and there will be an excess of sodium carbonate. Add phenol-phthalein and neutralize slowly with N/10 nitric acid. Add about 1 c.c. more of the acid, shake, and add solution of sodium carbonate drop by drop till the clear solution is just faintly pink. Add excess of potassium ferrocyanide and the solution becomes strongly alkaline, due to the reaction between the basic zinc carbonate and the potassium ferrocyanide. Titrate with N/10 nitric acid. Result equals the zinc less what has been precipitated by the ferrocyanide originally present (S).

(*F*) Zinc.—Add sodium carbonate as in previous test then sufficient silver nitrate (as shown by *D*) to precipitate all cyanides, ferrocyanides, etc., and the whole of the zinc will be precipitated as basic carbonate and there will be an excess of sodium carbonate remaining in the solution. Add phenol-phthalein and neutralize as in last test. Add excess of potassium ferrocyanide and titrate with N/10 acid. Result equals the whole of the zinc, plus any copper or cadmium which may be present in small quantities, (Z). In all of the above tests 50 c.c. of the original cyanide solution is taken. If the standard solutions used are N/10 nitric acid, and a solution of silver nitrate containing 13·05 g. per liter then the following are the factors for the different results:—

Total cyanide (as KCy)	$=T\times0{\cdot}02\%$.
Protective alkali (as KOH)	$=p\times0{\cdot}0112\%$.
Alkaline hydrate (as KOH)	$=h\times0{\cdot}0112\%$.
Alkaline carbonates (as K_2CO_3)	$=(p-h)\times0{\cdot}0276\%$.
Ferrocyanide (as K_4FeCy_6)	$=(Z-S)\times0{\cdot}0351\%$.
Zinc	$=Z\times0{\cdot}0081\%$.

Electromotive Force of Metals.—The most important contribution to the theoretical side of the subject that has recently appeared is an article by Prof. S. B. Christy having the above title, which was published in Vol. XXX. (p. 864) of the *Transactions of the American Institute of Mining Engineers.*

In the following review considerable matter of interest has been omitted, attention being called only to those sections which bear most directly on the cyanide

process. In the original paper the results if his determinations of the E.M.F. of various metals and ores in solutions of potassium cyanide of different strengths are given. A portion of the table is as follows:—

	Strength of KCN Solutions.					Strength of KCN Solutions.			
	M/1 (6·5%)	M/10 (0·65%)	M/100 (0·065%)	M/1,000 (0·0065%)		M/1 (6·5%)	M/10 (0·65%)	M/100 (0·065%)	M/1,000 (0·0065%)
	Volts.	Volts.	Volts.	Volts.		Volts.	Volts.	Volts.	Volts.
Gold	+0·37	+0·23	+0·09	−0·38	Cuprite	−0·43	−0·55	−0·57	.....
Silver	+0·33	+0·15	−0·05	−0·36	Bournonite	−0·50	−0·55	−0·56	.....
Copper	+0·81	+0·62	+0·37	+0·16	Pyrite	−0·28	−0·42	−0·48	.....
Zinc	.....	+0·77	+0·59	+0·39	Magnetopyrite	−0·30	−0·40	−0·54	.....
Zinc amalgamated	+0·98	+0·82	+0·70	+0·44	Argentite	−0.28	−0·56	−0·55	.....
Lead	+0·13	+0·05	+0·01	.....	Stephanite	−0·54	−0·55	−0·52	.....
Mercury	−0·09	(?) +0·01	−0·11	.....	Fahl ore	−0·36	−0·52	−0·52	.....
Iron	−0·17	−0·24	−0·24	.....	Arsenopyrite	−0·40	−0·45	−0·54	.....
Bornite	+0·45	+0·25	−0·16	.....	Stibnite	−0·56	−0·56	−0·56	.....
Copper glance	(?) +0·29	+0·25	+0·05	−0·44	Ruby silver	−0·54	−0·53	−0·54	.....
Chalcopyrite	−0·20	−0·34	−0·44	.....	Blende	−0·48	−0·52	−0·55	.....

In above table M=one gram-molecule of KCN (65 g.) dissolved in 1, 10, 100 or 1,000 liters of water.

The meaning of the signs + and — may not be clear to those who have not kept in touch with the modern theories of electro-chemistry, and for their benefit some explanation is necessary. In order to understand just what they signify, a clear idea must be had of the nature of solutions.

The phenomenon of osmosis and the pressure produced by it have long been known, but it remained for Pfeffer to show how to measure this pressure, and for Van't Hoff to prove that it followed the laws of gases in every particular, and that in a solution "the osmotic pressure of a dissolved particle is exactly equal to the gas pressure of a gaseous particle at the same temperature and concentration." That is to say, for example, in a solution of sugar in water each molecule of sugar in the solution will exert exactly the same pressure as would each molecule of any gas, such as hydrogen, of equal molecular concentration and at the same temperature and volume, or, in other words, the molecules of sugar in the solution obey exactly the same laws as if they were gaseous particles.

It was soon found that there were exceptions to the rule, and that some substances gave abnormal osmotic pressure when in solution. Those acting in this manner comprised almost all the bases, acids and salts, and until Arrhenius cleared up the difficulty it was a great stumbling block for the new theory of solutions. He proved, however, very conclusively that these substances when in solution are dissociated, to a greater or less extent depending on the degree of dilution into so-called ions. The molecule of potassium chloride, for example, would dissociate with the ions K (potassium) and Cl (chlorine), the metallic ion (K) carrying a charge of positive electricity, and the other a negative charge. This dissociation does not seem so strange when we remember that some gases give abnormal vapor densities, and that it is now fully established that this deviation from the law is due to dissociation of the molecule.

One point that is of special interest in this connection is that only those substances conduct the electric current which are at least partially dissociated, and therefore the conductivity is due to the dissociated parts or ions. Every one is

familiar with the fact of vapor tension or pressure and knows that when a solution or solid evaporates into a closed space an equilibrium is established at a certain definite pressure for a certain temperature. Nernst reasoned as follows: "If, in accordance with Van't Hoff's theory, we assume that the molecules of a substance in solution exist also under a definite pressure, we must ascribe it to a dissolving substance in contact with a solvent, similarly a power of expansion, for here also the molecules are driven into a space in which they exist under a certain pressure. It is evident that every substance will pass into solution until the osmotic partial pressure of the molecules in the solution is equal to the solution tension of the substance." Applying this principle to metals, suppose a metal be placed in water—the metal, owing to its solution pressure (P) tends to send ions into solution, these ions being charged with positive electricity, leave the metal negative and there is soon formed the so-called double layer of Helmholtz, that is, the positive ions in the solution and the negative metal attract each other and a certain potential difference is produced. Solution of the metal can only go on so long as the solution pressure (P) is greater than the electrostatic attraction of the double layer. This is in pure water—with a metal in a solution of one of its salts another force comes into play, due to the metallic ions of the metal already present. The osmotic pressure (p) of these ions opposes the entrance of new ions of the same kind. If the osmotic pressure is exactly equal to the solution pressure of the metal the latter will yield no ions. It will not become negatively charged and no double layer will form, consequently no potential will be produced. If the osmotic pressure is less than the solution pressure ions of the metal will not go into solution until P=p, and the metal will be negatively electrified and the solution positively, and an electric double layer will be formed and a potential difference established and the direction of the positive current will be from the metal to the solution. When the osmotic pressure is greater than the solution pressure the reverse action takes place and metallic ions from the solution carrying their positive charges are precipitated on the metal and the solution becomes negative and the metal positive, and the positive current travels from the solution to the metal. This action goes on as in former case until P=p.

We are now in a position to understand the meaning of the signs + and — in the table, the + corresponding to the second case P>p, that is, the metal tends to dissolve in the solution. The — sign corresponds to the last case P<p, that is, the metallic ions in the solution tend to precipitate on the metal, and unless outside energy is brought into play the metal will not dissolve.

To make the matter still clearer, take the common Daniel cell containing zinc in zinc sulphate and copper in copper sulphate. It has been found by experiment that zinc in zinc sulphate is + (P>p) with a potential difference of +0·521V, and that copper in copper sulphate is —(P<p) with a potential difference of —0·585V, hence in the combination of the two the zinc tends to go into solution with a force equal to 0·521V and the copper ions in the solution tends to precipitate on the copper (and producing a current in the same direction as the zinc ions) with a force equal to 0·585V, and as these two forces both act in the

same direction the total voltage of the cell will be equal to their sum, *viz.*, 1·10V. It may be represented in this way:—

$$Zn/ZnSO_4—CuSO_4/Cu$$
$$>0{\cdot}521V. \quad >0{\cdot}585V.$$
$$\text{Total,} \quad >1{\cdot}10V.$$

The arrows indicate the direction of the current.

If both metals had had P>p then the two forces would have been in opposite directions and the voltage of the cell would be the difference between the two. Take, for example, Zn in M/10KCN and gold in M/KCN, the result (see table of E.M.F.) would be expressed as follows:—

$$Zn/KCN—KCN/Au$$
$$> +0{\cdot}77 \quad +0{\cdot}23 <$$
$$> +0{\cdot}54V$$

and the E.M.F. of the couple would be 0·54V.

Knowing now the meaning to be attached to the signs, as pointed out by Prof. Christy, many points of interest will be found in the table bearing on the solubility of the various substances in potassium cyanide. The action in copper minerals is worthy of note, apparently showing that bornite and copper glance are soluble in solutions of as high dilutions as M/10 (0·65%) and the latte even at M/100 (0·065%); bornite, however, in a solution of that strength being insoluble. Chalcopyrite and all the other sulphides given are seen to be strongly electro-negative (insoluble). Prof. Christy calls attention also to the fact "that a particle of gold in contact with a particle of pyrite forms a galvanic couple in M/1 or 6·5% KCN equal to +0·65V; in M/10 or 0·65% KCN solution +0·65V; and in M/100 or 0·065% KCN +0·57V." Between zinc and gold under the same circumstances in solutions of M/1, M/10 and M/100 there are voltages of +0·54V, +0·50V and +0·77V, the zinc going into solution and the gold being precipitated. According to these figures, zinc should readily precipitate gold from very dilute solutions, and its failure to do so in practice may be due to the formation of films of cyanide or zinc hydrate on the surface of the gold, thus preventing contact. The fact that the addition of a small amount of potassium cyanide in the zinc boxes starts precipitation again seems to favor this explanation. As to gold, it ceases to dissolve in potassium cyanide at some point between M/100 and M/200 and that at M/1000 it is quite strongly negative.

On plotting the results obtained with solutions of various strengths it was found that the voltage curve crossed the zero point at a dilution of 0·044% KCN, that is, gold ceases to have any tendency to dissolve in solutions weaker than this. But much weaker solutions have been used in practice, and Prof. Christy's experiments show that solutions as dilute as 0·00325% KCN or possibly even so dilute as 0·0016% have a solvent action on gold. This apparent contradiction he explains in a very satisfactory manner, as will be shown later in this article. In order to understand his explanation it is necessary to become familiar with his method of determining the E.M.F. of the different metals, etc. For this Ostwald's normal electrode was used, which consists of mercury covered with a layer of mercurous chloride and a normal solution of potassium chloride. This is contained in one vessel and the metal to be tested is placed in another con-

taining the KCN solution, the two vessels being connected by a siphon filled with a solution of potassium chloride. The E.M.F. of the normal electrode has been very exactly determined as —0·56V. That is, the mercury ions of the solution tend to precipitate themselves on the surface of the mercury with a force of 0·56V. In other words, the positive current tends to flow through the solution to the mercury, the conditions in the complete cell being as follows:—

$$\text{An/KCN—KCl—}Hg_2Cl_2\text{/Hg}$$

$$\underset{0\cdot09}{\longrightarrow} \qquad \underset{0\cdot56\text{V.}}{\longrightarrow}$$

$$\underset{0\cdot09+0\cdot56=0\cdot65\text{V.}}{\longrightarrow}$$

Suppose a solution is taken of KCN of 0·065% and in determining the voltage of the complete cell find it to be 0·65V, it is plainly evident that the E.M.F. due to the gold is +0·09V, being the difference between the total voltage 0·65 and that of the normal electrode 0·56V. It is also evident that the current at the gold electrode is in the direction of the arrow.

Suppose now a solution of KCN of 0·0065% is used in place of the stronger one and on determining the E.M.F. of the combination it is found to be +0·18V. It is plain that the gold no longer tends to go into solution ($P < p$) and that the current due to it is reversed, thus:—

$$\text{An/KCN—KCl—}Hg_2Cl_2\text{/Hg}$$

$$\underset{0\cdot38\text{V.}}{\longleftarrow} \qquad \underset{0\cdot56\text{V.}}{\longrightarrow}$$

$$\underset{\text{E.M.F. of cell } 0\cdot18\text{V.}}{\longrightarrow}$$

Here are two opposing forces, and since that of the mercury ions is the stronger, it determines the direction of the current in the cell, but owing to the counter action of the gold ions it has only a force of 0·18V.

According to Prof. Christy, the action of a couple of this character will continue and the gold dissolve *"so long as the E.M.F. of the combination is greater than zero* and, as we have seen in my experiments, long after the electromotive force of the gold in the dilute cyanide solution has become zero. For the tendency of the mercury ions to discharge into the mercury electrode can only effect its purpose and cause a current by the simultaneous solution of the gold, that is, the tendency of the positively electrified ions of mercury to discharge themselves can cause the gold to dissolve long after its own electromotive force has ceased."

He then goes on to show that in the oxygen of the air we have a substance that acts practically in the same way as the mercury ions, producing a current that continues long after the E.M.F. of the gold has fallen below the zero point. This he proves by a very simple experiment made as follows: Two small porcelain cups were taken, one filled with KCN solution freed from oxygen and the other containing a similar solution saturated with oxygen. The two vessels were then connected by a siphon and a gold electrode placed in each and connected through a galvanometer and resistance coil. A current was found to flow through the solution from the electrode in the cup containing no oxygen to the one in the cup containing oxygen. In one experiment cited the electrode

in the cup free from oxygen lost 1·28 mg. and the other 1·73 mg. Many other experiments showed that the current flowed in the same direction and that there was a solution of the gold in the cup containing no oxygen. The fact that more gold was dissolved in the cup containing oxygen than in the other he explains as being due to local action between the gold and the hydroxide (OH) ions. The appearance of the electrodes is also said to corroborate this explanation, for the one in the cup free from oxygen was more evenly acted on than the other, the latter being "eaten into in a remarkable manner."

Using hydrogen dioxide instead of air in the cell his results were even more conclusive, the gold electrode in the cup containing no oxidizer dissolving more freely than in the one containing the dioxide. In one case the former lost 13·25 mg. and the latter 9·2 mg., and in still another the losses were 24·06 mg. and 13·25 mg., respectively. In both cases the electrode in the solution containing no oxidizer suffered the greater loss.

The peculiar fact discovered by McLaurin,[9] that the maximum solubility of gold in cyanide is in a solution containing between 5 and 10% KCN is explained as due to the fact that under this condition the sum of the two forces tending to dissolve the gold is greatest. The E.M.F. of the gold has reached nearly its highest point and the E.M.F. of the oxygen is greater than in more concentrated solutions, for McLaurin proved by his experiments that the more concentrated the cyanide the less the amount of oxygen dissolved.

Here are two forces bearing an inverse relation to each other that tend to dissolve the gold, and their maximum effect is at the dilution named, *viz.*, 5 to 10% KCN.

From the results of his experiments Prof. Christy concludes that in the cyanide process as practiced the solution of the gold is probably due to local action between it and the hydroxyl (OH) ions (formed by the action of O and H_2O) of the solution, and that for all practical purposes an aërated cyanide solution of less than 0·001% KCN is without action in gold. He also states "that the differences of E.M.F. of metals in dilute cyanide solutions do not give much support to the so-called 'selective affinity' of dilute cyanide solutions for gold, the only common metal that shows any indication of such favorable action being copper."

Assay of Zinc Precipitates.—Charles H. Fulton and Charles H. Crawford[10] first tried the scorification method and found it very unsatisfactory, the results obtained being low, evidently caused by excessive volatilization and loss in the slags. The crucible method was then used and found to give the highest average result (after correction for loss in slag) on gold but not on silver. The loss of precious metals in the slag was found to be very variable and while the method in many cases gives the highest results in others it gives low ones, although the conditions as to charge and heat are the same in all cases. The most satisfactory charge by this method was one recommended by Magenau, *viz.*, 0·1 assay ton precipitates, 70 g. litharge, 5 g. sodium carbonate (dry), 1 g. flour, 5 g. silica and 2 g. borax glass. A combination method was then tried, the precipitate being

[9] *Journal of the Chemical Society*, London, LXXXIII., p. 731.
[10] *School of Mines Quarterly*, January, 1901.

first boiled with nitric acid and then salt solution added to precipitate the silver, as well as some lead acetate and sulphuric acid. The precipitate was filtered, washed and scorified. The results for gold were found to be far too low, while for silver they were higher than by the crucible assay. This seemed to indicate that some of the gold had dissolved in the nitric acid and tests made proved that such was the case. This method was replaced by one using sulphuric acid instead of nitric acid as follows: 1·1 assay ton of precipitate was heated with 20 c.c. concentrated sulphuric acid and 60 c.c. water. This was boiled for one hour, cooled, diluted to 100 c.c., and 75 c.c. salt solution, and 20 c.c. of lead acetate solution added, allowing the precipitate to settle for one hour, then filtered, washed and dried. Care was taken to wash the precipitate into the point of the filter. The paper was burned off at a very low heat and the residue scorified until half covered over in the scorifier, then poured and the button cupelled. From 30 to 40 g. lead were used. The results were good and as uniform as can be expected with material of this kind. The gold is lower than in the crucible assay (about 6 oz. per ton) while the silver is higher. The slag corrections are relatively small. In conclusion the authors recommend either the combination sulphuric acid method or the crucible method, preferably the former. In using the sulphuric acid method care must be taken that the acid contain no nitric acid. The slag and cupels should be reassayed in order to add the proper corrections.

Zinc versus Electrolytic Precipitation.—(By Philip Argall.)—In THE MINERAL INDUSTRY, Vol. VI., I stated that "the method of precipitation by means of zinc has been very often criticised, but nevertheless it has stood the test of time, and for solutions running from 0·05% cyanide upwards, and low in gold, it is likely to continue for a considerable time to come the best precipitant of gold from cyanide solutions. To this strength at least electrical methods have a fair field; for solutions carrying over 0·10% cyanide I cannot see the slightest chance for electrical precipitation to compete with zinc."

A few months after writing the above, the results of large working tests with zinc alloys and couples clearly demonstrated that for any strength of solution, zinc can at least hold its own against electrical precipitation. Later when the process was in daily use, sundry improvements in details brought up the results considerably beyond my expectations. Complete records covering a period of 17 months, during which about 150,000 tons of solution were treated, showed that the average value of the solution entering the precipitators was 0·068 oz. gold, while that leaving was 0·005 oz. gold. The average strength of the solutions in cyanide being 0·031%, the precipitation of gold from these low-grade solutions is therefore 92·6%. A careful list of all the costs incidental to this precipitation for the entire period of 17 months showed that the actual expense of treating one ton of solution and marketing the bullion, was 1·5 cents. Reckoned on a basis of bullion recovered, the costs per oz. were: Zinc, etc., 12c.; crucibles, 4c.; acid, 1·106c.; soda, 0·4484c.; borax glass, 1·6036c.; niter and minor fluxes, 0·146c.; litharge, 0·306c.; coal and coke, 0·74c.; labor, 6·8c.; unclassified, 0·29c.; total, 23·84c.

The average assay of the wash water for December, 1900, showed 0·045 oz.

gold and 0·032% KCN before precipitation and 0·003 oz. gold and 0·028% KCN after precipitation.

Continuous samples of the solutions entering and leaving the precipitators were taken off and assayed every 12 hours, hence the foregoing averages for December, 1900, are based on two samples per day for 31 days, or 62 samples for each precipitator. The record for the 17 months previously described was taken in a similar manner, and all items of cost carefully tabulated; the results, therefore, are correct in all practical details for commercial work.

The precipitation averaged 94% and the gold value of solution leaving the precipitators was from 4 to 6c. per ton. There is nothing exceptional about these results, which represent what can be done with zinc under ordinary working, and indicate the conditions against which electrical precipitation must compete. The zinc consumption in the table is excessive, on account of close clean ups when active zinc was destroyed in order to recover values; this is a matter of importance in a custom mill, but of little consideration in a mine plant where the gold stock in the precipitators does not represent a cash expenditure of $20 per oz. Making allowance for this item, the cost could be reduced to 1·25c. per ton of solution, and even to 1c. per ton when working on a large scale.

The precipitation of the precious metals on zinc being so far perfected that solutions containing but a trace of cyanide and a few cents per ton in precious metals could be treated profitably, more attention was paid to a thorough and complete washing of the tank charges with fresh water.

It was known that in charges of from 25 to 30-mesh roasted ore containing 25% of material passing 200-mesh screen, the washing of the finer material was a difficult and tedious operation. On a large scale, I have used as much as 2 tons of fresh water per ton of ore in the charge, and in exceptional cases, 3 tons, exclusive of the residual water discharged with the tailings; while for the last three years my practice has been to pass through the charges not less than 1·5 tons of fresh water for each ton of ore, and where circumstances permitted, from 2 to 2·5 tons for each ton of ore.

This practice necessarily gave very weak terminal solutions, the final drains from the tanks seldom showing more than a trace of cyanide but not less than 3c. in gold per ton, unless the washing was carried up to or beyond two parts of water to one of ore. Hence complete washings are very important.

This work demonstrated further that fine and coarse ore, *i.e.*, from 50 to 150-mesh, should not be worked in tanks with ore below 200-mesh in either a dry or wet crushing process, and that quicker and better results can be obtained by working the infinitesimally fine ore separately from the coarser. Ores of 200-mesh can be as easily leached as ores of 30-mesh, if the usually light and flocculent material is removed that fills up the interstitial space between the 200-mesh particles, retarding or entirely preventing percolation. This light material is here designated as infinitesimally fine ore. By experiment it was found that the removal of the infinitesimally fine material in 150-mesh product to the extent of but 20%, rendered an impervious ore amenable to rapid percolation. I do not lose sight of the fact that in dry crushing, the fine and coarse ores are so well mixed that they are readily and cheaply leached together;

but I wish to go on record as stating that with ores of $15 per ton gold value or upwards, better work can be done by removing the infinitesimally fine ore and subsequently treating the coarse and fine material separately.

Returning to the weak solution of wash water, while the final drains were about as given, the average solution passing to the precipitators was much richer, as it contained solution from tanks of various stages of completion.

The determination of the values in these low-grade solutions, in a quick, cheap and commercially accurate manner, gave at first quite a little trouble. The ordinary method of evaporating 1 or 2 assay tons in a lead tray, and then rolling up and cupelling the foil, did not give weighable results; for some time, therefore, we were forced to evaporate 500 c.c. of solution for each sample; a long and tedious process.

Experiments on various precipitants were taken up, zinc dust, which had proved so effective in large scale operations, being among the very first, but in this small way it was found wanting; however, on moistening the powdered zinc with lead acetate, and agitating for two hours, excellent results were reached. The method was used for several months. On further and more complete investigation, however, the following assay method for the zinc precipitation of gold in low-grade cyanide solution was adopted, which gave quick and perfectly reliable results, and was used for all low-grade solutions to the exclusion of other methods.

Take 500 c.c. of the solution to be assayed, or for greater convenience, prepare a measuring flask to hold 20 assay tons of the solutions. Take a tall beaker, add 7 g. of zinc dust, and pour in the 20 assay tons of solution; next add 10 c.c. of commercial sulphuric acid, stir well with a glass rod, and cover with a watch-glass. When the action begins to fall off, add a further 10 c.c. of acid. The precious metals will be completely precipitated in from 10 to 20 minutes, but the solution had best be left in the beaker till the zinc is practically dissolved, usually occupying 40 minutes. A smaller quantity of zinc should not be used, and if the gold and silver is over 0·05 oz. per ton, 10 g. should be taken.

When the action is completed, filter, add 2 g. of silica to the residue on the filter-paper, fold, place in a 10-g. crucible, incinerate in the muffle, remove crucible and when cool add 10 g. each of flux and litharge, thoroughly mix in the crucible; fuse, cupel, weigh and part in the usual manner. The flux used consisted of 42 parts potash, 84 sodium bicarbonate, 42 borax glass, and 9 of flour. Should copper be present in solution, a larger proportion of flux will be required, and scorification may be necessary. The solution on which this assay method was used varied from 0·100 to 0·001 oz. gold per ton, and from 0·035% to 0·005% KCN, though it can be used on any solution if sufficient zinc dust is added to precipitate all the precious metal present.

This assay method was tested against evaporation to dryness with litharge and assaying the residue, and with ordinary care was found to give most excellent results. A few of the tests made on 20 assay tons of solution are given on the following page. These tests are from daily routine work, and show that the assay by the zinc method is as safe and reliable as that by evaporation. Its advantages over the latter method are that it is more economical, both in time and expense, and requires less attention.

	A.	B.	C.		A.	B.	C.
	Oz.	Oz.	Oz.		Oz.	Oz.	Oz.
Evaporation	·004	·002	·006	Evaporation	·098	·005	·008
Zinc dust	·004	·004	·004	Zinc dust	·087	·005	·008
Evaporation	·096	·0085	·004	Evaporation	·061	·007	·008
Zinc dust	·087	·0082	·0088	Zinc dust	·062	·008	·003
Evaporation	·100	·008	·003				
Zinc dust	·100	·008	·004				

Mr. C. W. Merrill had some tests made with this zinc assay on solutions containing 0·03% copper which gave results several per cent. lower than the method in use at his works. Upon investigation the discrepancies were found to be due to losses subsequent to precipitation; when 10 to 20 assay tons of a solution carrying 0·8 oz. gold, and 0·4 oz. silver per ton were used, no trace of gold or silver was found to have escaped after evaporating and assaying the filtrate.

A series of assays was then made with the following results:—

Method.	Assay. Tons.	Gold.		Silver.		Remarks.
		Oz.	Value.	Oz.	Value.	
Argall	8	·06	$1·20	·33	$0·16½	With 40 g. of flux.
Scorification	8	·06	1·20	·34	0·17	Zinc precipitation.
Evaporation	4	·06	1·20	·34	0·17	
Evaporation	4	·062	1·24	·34	0·17	Front row in muffle.
Argall	8	·059	1·18	·325	0·16	With 40 g. flux.
Scorification	8	·06	1·20	·325	0·16	Second row in muffle.
Evaporation	4	·06	1·20	·32	0·16	

It will be observed that the correspondence between the methods is very close. More care, however, was taken with the tests than is usual in ordinary practice. The evaporation method was more rapid, but this may be partially accounted for by the fact that only 4 assay tons were used; moreover the operator was hampered by lack of conveniences for carrying out the zinc dust method.

Mr. Merrill states that the results marked "Argall" were obtained by precipitating 8 assay tons with 7 g. of imported zinc dust (2·75% lead), and adding two lots of 10 c.c. each of sulphuric acid, filtering as soon as the zinc was practically all dissolved, using a rapid filter-paper, washing twice (this is not necessary), sprinkling with 4 to 5 g. of silica, transferring to crucible and burning at low temperature. 40 g. of flux were used, two-thirds being mixed with the ash, etc., and the remainder used as a cover. The zinc dust scorifier results were obtained by precipitating and filtering exactly as before. 25 g. of granulated lead were taken; one-third being put in the bottom of a 2·5-in. scorifier and one-third sprinkled over the filter-paper and precipitate, which was folded and covered in scorifier with the remaining lead. This was then dried at the muffle door and scorified for 10 minutes. The evaporation results were obtained by evaporating 4 A.T. to one-third bulk in a stoneware saucer, adding 70 g. of mixed flux (litharge 48, silica 20, charcoal 1·8), drying, mixing with 14 g. of soda ash, wiping out saucer with filter-paper moistened with dilute nitric acid, and adding this with a little litharge on top of charge, which was melted 25 minutes.

Mr. C. A. Hoyt, who used this zinc-dust assay method for some time, gives the following details as to results:—

The filtration from the zinc precipitate was conducted in 15 funnels over a

V-trough which led out of the building, this being the quickest way to filter. For 20 assay tons of the solutions a slightly heaped teaspoonful of zinc dust and about 10 to 15 c.c. commercial sulphuric acid were used. The actual precipitation is probably completed within 15 minutes, but it is better to let nearly all the zinc dissolve before starting to filter. The time required for handling 15 solutions was about four hours, as follows: Precipitation, 40 minutes; filtering, 30 minutes; burning filter and precipitate in muffle, 10 minutes; cooling crucible and fluxing same, 30 minutes; fusion in hot furnace, 30 minutes; slagging and cupelling, 40 minutes; parting and weighing, 60 minutes. This is a rough estimate of the average time required for 15 solutions, and no doubt the time could be shortened with better facilities.

The assay method is here published with the hope that it may prove as useful to others as it has to myself for rapidly and accurately determining the gold and silver contents of low-grade cyanide solutions.

REVIEW OF ANALYTICAL CHEMISTRY OF GOLD AND SILVER DURING 1901.

BY EDMUND H. MILLER.

THE detection of small quantities of gold and silver is described by Luther Wagoner[1] giving methods of determining infinitesimal quantities of gold and silver by cupellation and measuring the bead by the microscope and calculating its weight from the diameter. Tested in this way ordinary assay reagents, as sodium salts, acids, lime, borax, etc., all contained silver, while potassium cyanide showed both gold and silver.

A variety of rocks, as granite, sandstone, syenite, marble, etc., contained both gold and silver. Gold, from 21 to 1,130 mg. per 1,000 kg.; silver, from 201 to 15,430 mg. per 1,000 kg. In sea water gold was found to the extent of 11·1 mg. per metric ton, or about $0·0067 per ton of 2,000 lb.

Prof. Richards of Lehigh[2] describes the measurement of gold and silver buttons obtained by quantitative blow-piping by a new kind of scale. "The idea is to make two metallic edges, perfectly straight, lying on a flat surface, touching each other at one point and held apart at the other extremity by a set-screw; so that the point 100 may indicate a fixed width or separation of almost exactly 1 mm." In using the scale the button is put into the groove, the scale inclined slightly and tapped until the button wedges itself, and the diameter read off on the scale to tenths of a millimeter. For further directions and the necessary tables the original article must be consulted.

E. A. Smith[3] has collected and reviewed the best methods for assaying of complex gold ores. With a few exceptions, which are brought out in the discussion printed with the article, the article presents recent American practice, and is useful for students, as it gives an excellent résumé of the methods for certain ores. It contains nothing new to American assayers.

Holborn and Day[4] give the melting point of pure gold as 1,063·5°C.

[1] Paper read before the American Institute of Mining Engineers, November, 1901.
[2] *Journal of the American Chemical Society*, April, 1901, p. 203.
[3] *Transactions of the Institution of Mining and Metallurgy*, Vol. IX., p. 315-61.
[4] *American Journal of Science*, February, 1901.

L. W. Andrews[5] has devised a new method for the titration of silver by the use of iodide of starch solution, as originally proposed by Pisani, but under entirely different conditions, as the reaction takes place in a nitric solution in the presence of both ferrous and ferric salts. The reaction is as follows:—

$$2AgNO_3+2Fe(NO_3)_2+I_2=2AgI+2Fe(NO_3)_2.$$

The end point is the blue of the standard solution, so no other indicator is required, and in this respect the method has the same good feature as potassium permanganate. Preparation of the solution—50 g. of washed starch are rubbed up with 8 or 9 g. of sublimed iodine, and the mixture with 100 c.c. of water, is transferred to a wide tube of heavy soft glass, sealed and heated for several hours in boiling water; then diluted and filtered through a hardened paper. From this solution N/20, N/50 or N/100 solutions can be prepared by dilution. The strength of the solution must be determined by titration against silver and not against sodium thiosulphate for a portion of the iodine present is in a condition (analogous to an alkyliodide) which reacts with silver but not with thiosulphates.

The conditions for titration are as follows: The solution is to be acid with nitric acid, but must not contain over 5% chlorides, bromides, iodides, cyanides, thiocyanates; also, mercury salts and arsenic or antimony in the triad condition must not be present. Sufficient ferrous sulphate or nitrate must be added so that the iron present will equal the silver; then an equivalent quantity of the same ferric salt. An excess of iron salts is without influence. When very small amounts of silver are present (less than 20 mg.) the sulphates can be used, but if a considerable quantity of silver is to be determined, nitrates must be used to avoid the formation of silver sulphate. The iron salts are best kept in the form of sulphates, and before use converted to nitrates by a measured excess of lead nitrate. The titration should be made slowly with stirring in a casserole to give a white background. The end point is so sharp that variations in dilution are practically without effect. Copper and lead nitrates have no influence on the results.

For the determination of large quantities the author recommends that most of the silver be precipitated by sodium bromide, and the filtrate titrated by the iodide of starch method. The only drawback to this method seems to be the trouble of preparing the standard solution, and even though it does not displace the familiar and well proven methods of Gay Lussac, Mohr, and Volhard, it represents in its development an excellent piece of chemical work.

R. G. van Name[6] shows that while silver thiocyanate is not suitable as a means of determining silver gravimetrically on account of its solubility in an excess of alkali thiocyanates, yet it is an excellent means of estimating thiocyanic acid, by using an excess of silver nitrate, filtering on a Gooch crucible, and drying at 115°C.

A. Hollard[7] describes a method for the determination of silver in ores such as galena—by dissolving in nitric acid, etc., then electrolyzing from a cyanide solution, and finally titrating by Volhard's method and states that it can be applied to crude copper. Scorification seems simpler.

[5] *Zeitschrift fuer Anorganische Chemie*, 26, p. 175. [6] *Ibid.*, 26, p. 235. [7] *Ann. Chim. Anal. Appl.*, 6, 251-3.

GRAPHITE.

THE production of crystalline graphite in the United States during 1901 amounted to 3,967,612 lb., valued at $135,914, as compared with 4,103,052 lb., valued at $164,122 in 1900. As in previous years, the mines in the Ticonderoga district, N. Y., produced the greater part of the output, although the mines of Chester County, Pa., and Barton County, Ga., contributed considerable quantities. The mine in Clay County, Ala., which was inoperative during 1900, produced approximately 150 tons of crude graphite during 1901. The production of amorphous graphite in the United States during 1901 was 809 short tons, valued at $31,800. Under this head is included the so-called graphitic anthracite of Rhode Island, which is of structure between scaly and granular and contains as much as 52% C in selected samples, and the so-called Baraga graphite of Michigan, which in reality is a carbonaceous schist. In addition to the production stated above there has been considerable activity in developing graphite mines in South Dakota, Georgia, Montana, New Jersey and North Carolina, and in the aggregate some 25,000 tons of material has been mined and is awaiting the selection of proper concentrating processes to convert the product into salable form.

THE PRODUCTION, IMPORTS AND CONSUMPTION OF CRYSTALLINE GRAPHITE IN THE UNITED STATES.

Year.	Production. (a)		Imports.		Consumption.	
	Pounds.	Value. (b)	Pounds.	Value.	Pounds.	Value.
1897.....	993,138	$44,691	19 113,920	$270,952	20,107,058	$315,643
1898.....	1,647,679	82,385	30,199,680	743,820	31,847,359	826,205
1899.....	3,632,608	145,304	41,586,000	1,990,649	45,218,608	2,135,953
1900.....	4,103,052	164,122	39,228,560	1,390,141	36,401,612	1,554,263
1901.....	3,967,612	135,914	32,076,860	895,375	36,044,412	1,031,289

(a) Production of refined graphite only; of amorphous graphite there were produced 1,200 tons ($11,400) in 1897, 1,200 tons ($11,400) in 1898, 1,080 tons ($8,240) in 1899, 1,045 tons ($8,640) in 1900, and 809 tons ($30,800) in 1901. (b) Nominal.

Special interest has been attracted to the mineral graphite in recent years, due to its increased domestic production, prices and importation. For a long time

curious prejudices existed which hampered the development of the industry, and considerable confusion frequently resulted from the different names which have been used to designate the mineral—plumbago, black lead, pot lead, etc. Latterly the high prices of graphite and the small supply have done much to remove these prejudices, and the advent of artificial graphite, together with the attempt to market a variety of grades of graphite from new prospects have helped to develop the industry. The bulk of the supply of the best grades of graphite continues to be obtained from Ceylon, and probably amounts to from 75 to 80% of the total consumption of the United States. The great activity in the metal trade during the past few years has resulted in the increased consumption of crucible graphite and other high grades, which has been further augmented by the increased use of graphite as a paint pigment, as a lubricant, and in electrical work; for the last-named use no substitute for graphite has yet been found. The demand for a lubricant which will withstand the heat due to high pressure and high speed has led to the use of graphite, which fulfills these requirements. In December, 1901, United States Patent No. 697,996 was allowed to Mr. W. F. Downs, of Jersey City, N. J., for a lubricant consisting of particles of a solid lubricant coated with an oil in which it is insoluble and suspended in an enveloping oil with which the coating-oil is not miscible, which promises to increase largely the consumption of graphite for this purpose.

The preservation of the life of steel structures has demanded the attention of the civil engineers, and at many of the meetings of the engineering societies interested in structural iron work papers have been read during the past few years of the various means of prolonging the life of steel structures. The consensus of opinion is largely in favor of a carbon or graphite pigment in the paints or coatings used, and, as a consequence, the manufacture of graphite paint, using as a raw material the amorphous graphite from certain deposits in Michigan or the artificial product from the electric furnace, has been very greatly increased.

Alabama.—The Allen Graphite Co. operated a mine in Clay County, and was the only producer during 1901. The Alabama Graphite Co., with mines in Cleburne County, reported no production.

Michigan.—The Hathaway Graphite Manufacturing Co., with mines at L'Anse, Baraga County, reported an increased output of amorphous graphite for 1901; the product is of low grade and suitable for foundry facing, paint, and similar uses.

Montana.—The Crystal Graphite Co. shipped a few sample lots of graphite ore East, from its mines near Dillon, to test its suitability for crucible manufacture. The product is crystalline and of high grade, closely resembling the Ceylon variety.

New Hampshire.—The American Graphite Co. is reported to be erecting a refining plant at its mines in Merrimac County. A tunnel 120 ft. in length has been driven at the principal mine.

New York.—In the northern part of the State graphite occurs in schistose rock and, while seldom carrying more than 10% of mineral, it yields by far the greater part of the output of crystalline foliated graphite production of the United States. The production of graphite during 1901 from the two mines

owned by the Joseph Dixon Crucible Co., located at Graphite and Hague, near Lake Ontario, has not changed materially from that of the previous year. The mine and plant at Buck Landing, near Ticonderoga, and a plant at Johnsburg, N. Y., which began operations in 1900, were shut down owing to an insufficient supply of ore. The mine and plant at Pottersville is being enlarged and developed by the International Graphite Co., but the presence of a continuous and paying ore body has yet to be demonstrated. Gray Brothers, at Ticonderoga, have a promising prospect at Rock Pond, midway between it and Schroon Village; though little development has been done, surface outcroppings indicate a considerable body of low-grade ore. This property will be further exploited by a recently organized company.

Pennsylvania.—The only concern reporting a production of graphite during 1901 was the Philadelphia Graphite Co., whose mine is situated a mile east of Chester Springs, Chester County. The mineral occurs in two layers of disintegrated mica schist respectively 4 ft. and 6 ft. in thickness. In mining the drifts are run in on the hillside following the layers; the rock is so disintegrated that most of the graphite material can be removed with the pick and shovel without the aid of blasting. At the mill the ore is crushed in rolls and cleaned in a washer similar in principle to the common washer used at clay works. After washing it is again ground and further refined by means of air currents and separated into different grades. At another point, Byers, at the end of the Pickering Valley branch of the Philadelphia & Reading Railway, several miles below Chester Springs, graphite has been mined in considerable quantities in recent years. The ore is of a low grade and has been shipped to Reading and Bethlehem for use as a foundry facing. The graphite works at Byers were destroyed by fire in 1900. At Pikeland, Chester County, there is an abandoned graphite mine and refining plant which was productive a few years ago. Near Mertztown, in northern Berks County, a graphite mine and refining mill have been operated at intervals during the past 20 years, but no production was reported in 1901. The graphite occurs in a lenticular vein in a coarse-grained sandstone of a maximum thickness of 39 ft., which is mined with pick and shovel in galleries at different levels; 28% of the mined material is graphite. At Boyertown, in eastern Berks County, an abandoned graphite mine was re-opened in 1899 by the Boyertown Graphite Co. and a refining mill erected. The works, however, were not successful financially. Graphite occurs at other points in Pennsylvania, but, so far as is known, it has not been produced commercially except at the mines mentioned.

Rhode Island.—The Rhode Island Graphite Co. reports an increased output during 1901 from the mine at Arlington. The amorphous product variety is principally used as a foundry facing and for the manufacture of polishes.

South Dakota.—The graphite mine near Custer, Custer County, which yields a product stated to contain from 26 to 41% C, has not been developed owing to the low grade of the material and the cost of shipment to market.

Other States.—Several deposits of amorphous graphite have been reported from California, Colorado, and Texas. None of these, however, have as yet been proven of high value.

WORLD'S PRODUCTION OF GRAPHITE. (IN METRIC TONS.)

Year.	Austria	Canada	Ceylon. (d)	Germany.	India.	Italy.	Japan.	Mexico	Russia.	Spain.	Sweden	United States. (b)	Totals.
1896	35,972	126	10,463	5,248	(a)	3,148	215	620	(a)	*Nil.*	14	184	55,356
1897	38,504	396	19,275	3,861	61	5,650	204	907	(a)	(a)	99	450	69,311
1898	33,062	1,107	78,509	4,593	22	6,435	346	1,857	98	10	50	824	125,006
1899	31,819	1,105	29,037	5,196	1,548	9,990	55	2,305	29	(a)	535	1,648	80,992
1900	33,663	1,743	(c)	9,248	1,858	9,720	94	2,561	(c)	(a)	84	1,862	55,790

(a) Not reported in the government statistics. (b) Crystalline graphite. (c) Statistics not yet published. (d) The figures for 1897 and 1899 are exports; the enormous production in 1898 as reported in official government publications is not reflected in the exports for that year, which amounted to 24,849 metric tons.

Austria.—With regard to the genesis of graphite deposits, those of upper Styria, according to K. A. Redlich, are of sedimentary origin, which does not agree with the heretofore accepted opinion of Dr. Weinschenk that they are of contact metamorphic character. The graphite occurs in two forms, the one soft and flaky and the other hard and crystalline; both are found in the conglomerate near Truben; although the hard variety only occurs in the beds which have been folded or bent. Mr. J. L. Barvir refutes Weinschenk's theory that the graphite of southern Bohemia was formed by gaseous emanations containing carbon monoxide and offers the theory that it was derived from organic origin.

Canada.—The production of graphite during 1901 was 2,190 short tons, valued at $44,380, which was derived mainly from the Black Donald mine, at Brougham, Renfrew County, Ont. Owing to the distance from the railway the product can only be shipped to market during the winter. This deposit is of unusual size and is being developed 12 miles west of Calabogie station on the Kingston & Pembroke Railroad. The workings consist of open cuts and a shaft 80 ft. deep, from the bottom of which a drift on the vein extends 150 ft. northeast, going under Whitefish Lake. The vein stands vertically and at a depth of 80 ft. measures 22 ft. in width. The enclosing country rock on both walls is limestone. Hoisting is still done with a derrick and a 2-ton hoisting engine. Since opening the mines 4,000 tons of graphite have been shipped, of which about 1,800 tons represent the output for 1901.

India.—In the Ceylon deposits the graphite occurs in typical symmetrical veins, although crushed and altered by earth movements which have spent their energy upon the soft graphite and have consequently spared the granulite country rock. Weinschenk concludes that the graphite is of volcanic and not of organic origin, due, in all probability, to the action of vapors carrying carbon. He offers the suggestion that carbon dioxide and cyanogen compounds have played the chief part in its production. Among the associated minerals it is remarkable that, as at Passan, nontronite is one of the invariable decomposition products accompanying graphite.

The decline in the value of graphite has checked mining operations and many of the smaller mines have been abandoned. The larger pits yielding better qualities, and those of wealthy owners employing skilled European supervision, showed an increased output and prospered fairly. In Kurunegala only 50 plumbago pits were worked in 1900, as compared with 154 in 1899, and in the southern province only 30 acres were leased as against 117. A graphite mine 14 miles from Trivandrum, in Travancore, is worked by Cornish miners, and turns out more than 100

tons of graphite each month. The export of the mineral from Travancore in 1900 was 1,600 tons. Mr. T. L. Walker reports the occurrence of graphite in several localities in N.E. Kalahandi State. The deposits are in parallel beds and apparently of good quality. About 40% of the Ceylon product is imported into this country, approximately the same amount goes to England, while Europe takes the remainder. The Ceylon graphite that comes to America is imported directly by steamer in packages of a net weight of about 600 lb. each. It is graded in the order of its value into "lump," "chip," and "dust" graphite. The first grade consists of the larger and softer pieces, the second, as is indicated by its name, is made up of smaller lumps and fragments, while the dust graphite, the lowest in value, carries the bulk of the earthy impurities. These grades again are subdivided according to their brightness, or "boldness," the term used in the trade, and softness. The importations of European graphite into America is far less, relatively to the amount produced, than that from Ceylon, for the reason that for many of the uses to which the amorphous variety is put in Europe the domestic product has been substituted in the United States. While, of course, it is impossible to apportion with accuracy the relative amounts of graphite applied in its various uses, they are approximately as follows: In crucibles, 55%; stove polish, 15%; foundry facings, 10%; paint, 5%; lubricating, 5%; all others, 10%. The last item includes graphite for powder glazing, electrotyping, steam packing, and various minor uses.

Mexico.—A very fine variety of pencil graphite is mined at Torres, Mex., by an American company.

Artificial Graphite.

The manufacture of crystalline and amorphous "artificial graphite" by the sole producer, the International Acheson Graphite Co., at Niagara Falls, N. Y., has increased enormously, as is shown by contrasting the production in 1901 of 2,500,000 lb. with 860,750 lb. in 1900, and 405,870 lb. in 1899. Graphitized electrodes used in the electrolytic production of alkali and bleach consumed more than one-half of the output in 1901, while paints, pencils, lubricants, motor brushes, crucibles, and dry batteries absorbed the balance of the production.

PRODUCTION AND VALUE OF ARTIFICIAL GRAPHITE FROM 1897 TO 1901, INCLUSIVE.

Year.	Pounds.	Value.	Unit Value per Pound.	Year.	Pounds.	Value.	Unit Value per Pound.
			Cents.				Cents.
1897.....	162,382	$10.149	6·2	1900.....	860,750	$69,860	8·0
1898.....	185,647	11,603	6·2	1901.....	2,500,000	119,000	4·75
1899.....	405,870	32,475	8·0				

The decrease in the unit value of the total production from 8c. per lb. in 1899 and 1900 to 4·75c. per lb. in 1901 was largely due to the increased proportion of the amorphous variety produced.

The furnaces used in the Acheson process for making graphite and graphite electrodes commercially are similar to those used in Acheson's process for making carborundum (silicon carbide). They are built of brick in the form of a long, narrow trough lined with suitable refractory material. Graphite electrodes are

manufactured of petroleum coke and pitch like an ordinary carbon for arc lights, but a certain amount of some carbide-forming material, as silica or iron oxide, is introduced. The electrodes after baking are graphitized in a furnace heated to a temperature well above that of the volatilization of iron, aluminum and silicon and similar elements. That the temperature used in the Acheson furnaces is well above the volatilization point is demonstrated by the fact that the elements above named are condensed as oxides outside the furnace.

Anthracite coal is usually employed in manufacturing graphite for crucibles, paint, stove polish, etc. The furnace is filled with anthracite coal through the center of which runs a core composed of a carbon rod connecting the terminals of the furnace electrically. When cold, anthracite coal is a very poor conductor of electricity, hence the necessity for the core, which acts as a conductor and heats the surrounding anthracite when the furnace is started. Finally, the whole mass is raised to a very high temperature and converted into graphite. On cooling, the latter is removed from the furnace and ground to the desired fineness. The physical change produced by the Acheson process for manufacturing graphite electrodes is illustrated by the following table:—

Amorphous carbon electrodes:		Graphite electrodes:	
Density	1·90 ohm.	Density	2·19 ohm.
Electrical resistance per cu. in.	0·00124 ohm.	Electrical resistance per cu. in.	0·000320 ohm.

The high temperature volatilizes nearly all of the contained impurities, leaving from 0·1 to 0·5% ash. The electrodes show marked resistance to disintegration in the electrolysis of sodium chloride solutions, having from 2 to 3 times the life of the most resistant form of amorphous carbon (retort carbon) and from 3 to 7 times the life of artificial carbon anodes. Tests made on the graphite produced from anthracite show that it is free from amorphous carbon. The average product of the furnaces contain approximately 5% of ash, and is therefore far purer than the average natural graphite. When necessary, purer graphites are produced by heating to a high temperature for a sufficiently long time to volatilize and drive off all impurities. Anthracite treated in this way produced a graphite containing only 0·31% of ash, although the original coal carried about 15% ash. This small quantity of residual ash is undoubtedly due to the condensation of the vapors existing in the furnace when the current is cut off. Mr. Acheson has considered a plan by which these may be washed out during the operation of the furnace by the use of nitrogen or other inert gas, but commercial requirements have not as yet necessitated putting this into practice.

It is a remarkable fact that in spite of the large amount of work that has been performed by various experimenters on the conversion of amorphous carbon into graphite, half a century elapsed before a process was developed commercially. Over 50 years ago, with a battery of 600 Bunsen cells, Duprez attacked this problem; but it was only within a few years that a method was discovered which, with the electric current at Niagara Falls, produced in 1901, 2,500,000 lb. of graphite from artificial amorphous carbon.

Acheson artificial graphite electrodes are recommended for electrolytic and electro-metallurgical processes, the advantages claimed for them being long life, low porosity, high conductivity and great economy. The electrodes are made by

treating in the electric furnace amorphous carbon articles made up in the shape desired. The product is stated to be entirely free from amorphous carbon, and the percentage of impurity in the finished electrodes is given as 0·1%. The size of the electrodes is limited generally by the difficulties of manufacture. In rectangular shapes the cross section is limited to about 28 sq. in., and the length to 36 in. The width of a carbon is usually limited to 8 in. In round carbons the length is limited to 36 in., and the diameter is 5 in. These limits can be increased slightly when large amounts are ordered. Some striking results have been obtained in tests made in Germany with Acheson graphite electrodes in the electrolysis of sodium chloride solutions.

GYPSUM.

THE production of gypsum in the United States continued to increase greatly during 1901, the output amounting to 659,659 short tons, valued at $1,577,493, as compared with 484,202 short tons in 1900.

The increase in the production of gypsum in the United States during recent years has been remarkable. For the ten years previous to 1899 the annual output averaged a little more than 250,000 short tons, which has risen to the maximum output of 659,659 short tons in 1901. This rapid development has resulted mainly from two causes, one the increased use of plaster of Paris in the manufacture of wall plaster in modern buildings, and the other to the large quantities consumed in the manufacture of staff for the construction of temporary buildings, particularly those built for exposition purposes.

PRODUCTION OF GYPSUM IN THE UNITED STATES. (*a*) (IN TONS OF 2,000 LB.)

States.	1899.	1900.	1901.	States.	1899.	1900.	1901.
California	3,663	*e* 3,500	3,550	Oregon	500	450	(*d*)
Colorado	1,600	4,000	*b* 17,394	South Dakota	600	750	(*d*)
Ind. Ter. and Oklahoma	20,750	16,977	(*d*)	Texas	34,214	42,000	(*f*)
Iowa	51,958	92,201	*c* 213,419	Utah	1,700	2,947	(*d*)
Kansas	92,016	*e* 90,000		Virginia	12,773	10,895	15,236
Michigan	144,776	150,000	185,150	Wyoming	2,817	2,995	(*g*)
Montana	304	325	(*d*)	Other States	.....	.....	105,345
New York	39,390	42,874	119,565				
Ohio	25,000	25,000	(*d*)	Total	422,061	484,202	659,659

(*a*) Statistics reporting the amount quarried. (*b*) Includes Wyoming. (*c*) Includes Texas. (*d*) Included in Other States. (*e*) Estimated. (*f*) Included with Iowa and Kansas. (*g*) Included with Colorado.

GYPSUM IMPORTED INTO THE UNITED STATES. (IN METRIC TONS.)

Year.	Ground or Calcined.			Unground.			Value of Manufactured Plaster of Paris.	Total.
	Quantity.	Value.	Per Metric Ton.	Quantity.	Value.	Per Metric Ton.		
1897	2,707	$17,028	$6·29	165,812	$178,686	$1·08	$16,715	$212,429
1898	3,021	18,500	6·12	168,723	181,364	1·09	40,979	240,843
1899	3,317	19,250	5·80	199,724	220,603	1·10	58,078	297,926
1900	3,159	19,179	6·07	213,239	229,878	1·08	66,473	315,530
1901	3,156	19,627	6·22	238,971	238,440	0·99	68,603	326,670

PRODUCTION OF GYPSUM IN THE PRINCIPAL COUNTRIES. (*a*) (IN METRIC TONS.)

Year.	Algeria. (*b*)	Canada.	France. (*b*)	Germany. (*c*)		Greece.	India.	United Kingdom	United States.
				Baden.	Bavaria.				
1896	37,512	187,818	2,051,124	32,801	28,799	120	7,605	196,404	201,305
1897	36,750	217,392	2,004,339	40,702	26,153	51	8,187	184,287	272,498
1898	37,337	198,908	2,115,261	28,037	25,688	83	8,390	199,174	285,644
1899	39,950	221,862	1,807,454	29,419	29,727	81	6,546	215,974	382,891
1900	42,287	238,713	1,774,492	26,381	35,484	129	4,415	211,436	439,265
1901	(*d*)	266,533	(*d*)	(*d*)	(*d*)	671	(*d*)	204,045	598,529

(*a*) From official reports of the respective countries, except the statistics for the United States. (*b*) A part of the product is reported as plaster of Paris. In converting this to crude gypsum it has been assumed that the loss by calcination is 20%. (*c*) Prussia is a large producer of gypsum, but there are no complete statistics available. (*d*) Statistics not yet available.

THE GYPSUM CEMENT PLASTER INDUSTRY IN KANSAS DURING 1901.

BY E. HAWORTH.

EARLY in 1901 the American Cement Plaster Co. purchased the mills of the Salina Cement Plaster Co., at Dillon and Longford, closing the former. In June this company shut down the mill at Mulvane and later acquired the plant of the Great Western Co., at Blue Rapids. About two years ago the American Cement Co. bought a large tract of gypsum land at Acme, Tex., and is operating a large mill there, and in February, 1902, it acquired additional gypsum land in Indian Territory. In April the Sampson Cement Plaster Co., at Burns, was sold to A. D. Macky, who continued to operate the plant under the old firm name with offices at Burns. In the latter half of the year, the Alumanite Co., with mills near Dillon, was re-organized under the name of the Ætna Cement Plaster Co., and its mills put in operation. The Kansas Cement Plaster Co. changed its name to the Wymore Cement Plaster Co., with offices at Wymore, Neb. The Roman Cement Plaster Co. continued operation near Springvale throughout the greater part of the year.

Early in 1902 a general change was effected by the formation of the United States Gypsum Co., capitalized at $10,000,000, with offices at Omaha, Neb., which in addition to the works in Kansas, consolidated the following companies:—

Iowa.—Baker Plaster Co., Carbon Plaster Co., Cardiff Gypsum Plaster Co., Duncombe Stucco Co., Fort Dodge Plaster Co., Iowa Plaster Association, Mineral City Plaster Co., all of Fort Dodge.

Kansas.—Great Western Cement Plaster Co., Blue Rapids Cement Plaster Co., of Blue Rapids; Roman Cement Plaster Co., of Kansas City, and Blue Valley Plaster Co., of Omaha, Neb.

Michigan.—The Alabaster Co., of Alabaster; the Alabastine Co., Grand Rapids Gypsum Works, Gypsum Products Manufacturing Co., Michigan Plaster Co., Midland Plaster & Cement Co., all of Grand Rapids; New Buffalo Alabastine & Mineral Paint Mfg. Co., of Lansing; John McPhee, of Nelson; and Durr Plaster Co., of Grandville.

New York.—English Plaster Works, Otto B. English Plaster Co., Genesee Stucco Works, Big Four Plaster Co., all of Oakfield, N. Y.

Oklahoma.—Oklahoma Cement Plaster Co., of Okarche.

The Western mills not belonging to the United States Gypsum Co. are the American Cement Plaster Co., the Best's Keen Cement Co., at Medicine Lodge, and the Acme Cement Plaster Co., at Quanah, Tex., and Laramie, Wyo., Samson Cement Plaster Co., Burns, Kan., Ætna Cement Plaster Co., Kansas City, Mo., and Dillon, Kan., Best's Keen Cement Plaster Co., Medicine Lodge, Kan.

Technology.—The methods of handling gypsum and its products have not changed materially during the last few years. Rock gypsum is quarried similar to the methods followed for stone or coal, and the rock is crushed and calcined into plaster of Paris. Gypsum earth is taken directly from pits to calcining kettles and calcined, the difference in treatment being due to the physical structure; one is a rock, while the other is loose like sand. At Blue Rapids, quarrying is done at each of the three mills by tunneling or drifting into the bluffs, the rock being mined by the double-room and pillar system. Tramways are

laid, and the quarried rock carried by cars hauled by cable or other power. At the Great Western mine, the ground cars are drawn directly into the mill and the rock gypsum dumped beside the crusher. At Hope a shaft is sunk 80 ft. to the rock gypsum, which is hoisted to the surface, loaded on cars and drawn by the local freight engine to the mill a quarter of a mile away. At Medicine Lodge, gypsum occurs on high hills about 5 miles S.W. from the city where the factory is located. The rock gypsum is quarried from the hill tops in a manner similar to the general quarrying of building stone and hauled by team to the factory, where it is crushed and calcined.

Crushing at most of the mills is done by some modified form of the jaw crusher, which reduces the gypsum to a small size; it is then ground to a fine powder by the old-fashioned stone burrs formerly used in flouring mills. The Kansas mills use machinery manufactured at Enterprise or Leavenworth, Kan., or Grand Rapids, Mich. A few years ago Grimsley[1] gave a very good description of the machinery and other appliances used in Kansas. No changes of importance have been made since his report was published. The lime disintegrator manufactured by the Stedman Foundry and Machine Works of Aurora, Ind., has not yet been introduced into Kansas, although it is extensively used in Michigan and by the Western Plaster Works of Chicago.

The general method of handling gypsum earth is to remove the overburden by plow and scraper, as in railway grading, and loosen the gypsum earth by driving over it in different directions with an ordinary farmer's disc harrow, later using a horse scraper to haul the material to the mill. Detailed operations differ in various localities, depending upon the relative location of the mill and the pit.

Calcining is universally done by means of the old-fashioned kettle, which is described and illustrated in the article by Grimsley, already quoted. Crushed rock gypsum or gypsum earth, is placed in the kettle and heated to the proper temperature to drive off a part of the water of crystallization, the material being moved by mechanical agitators. When half the water of crystallization has been driven off, it is pronounced "done," a valve is opened and the calcined gypsum powder runs out by gravitation into a chamber having masonry walls, where it is allowed to cool. In a few mills, as the ones at Mulvane, Kan., and Marlowe, Ind. Ter., the calcined material is immediately elevated by suction power, a process which not only elevates the plaster to the proper chambers but cools it at the same time. In other mills the elevating is done by chain buckets which, while cheaper to operate, requires more time and does not have the advantage of properly cooling the plaster. The suction method is expensive in that a large amount of power is required for a short time only, necessitating a much larger steam capacity than that required for the slower bucket elevator.

The plaster, after elevating, is mixed with proper amounts of a retarder and fiber. The general practice is to use a patented mixer consisting of a hopper for the reception of the plaster, which feeds into a cylinder where it is thoroughly mixed and forced out by an auger. From the mixer it is taken to bins and finally put into bags or barrels on the lower floor, the plaster passing down through wooden pipes or conduits from the bins above in a manner similar to the grain conduits in grain elevators.

[1] *University Geological Survey of Kansas*, Vol. V., p. 96; also, THE MINERAL INDUSTRY, Vol. IV., p. 895.

IRON AND STEEL.

DURING 1901 the production of pig iron was 15,878,354 long tons, against 13,789,242 long tons in 1900, an increase of 2,089,112 long tons during the year, Despite this enormous increase in production which was only slightly exceeded by the production of 1898 against that of 1897, the active demand for iron and steel was such at the close of the year that iron and steel works of all kinds found difficulty in securing deliveries of pig, and importations of foreign pig were not unusual, more especially on orders from the Atlantic seaboard. Among the new plants begun in 1901 which will be completed in time to increase the pig iron output of 1902 are the following: A new 100-ft. stack for the Port Oram, N. J., works owned by Joseph Wharton, of Philadelphia, Pa. (A third furnace of the same size is to be added during 1902.) The St. Clair Steel Co., one of the subsidiary companies of the Crucible Steel Co. of America, is erecting an open-hearth steel plant at Clairton, Pa., and the St. Clair Furnace Co. is building three 500-ton blast furnaces at the same place. The steel will be absorbed by the Crucible Steel Co., and the plants are expected to be in operation about the middle of 1902. The completion of the new "B" furnace for the Iroquois Iron Co., on the Calumet river, South Chicago, Ill., during the latter part of 1901 makes the total daily capacity of the plant about 500 tons of pig iron. The plant is equipped with storage capacity sufficient to permit its annual ore supply to be brought down during navigation season, and the strongly built docks and eight Brown hoisting and conveying machines permit two vessels to be unloaded simultaneously at the rate of 400 tons of ore per hour. The stock ore piles are situated close to the furnaces to avoid rehandling. The plant was designed by Julian Kennedy, of Pittsburg, Pa. The new Searles furnace of the La Follette Coal, Iron & Railroad Co., of La Follette, Tenn., is expected to be blown in by July, 1902. Its capacity is about 100,000 tons per annum. The Pioneer Furnace, of the Republic Iron & Steel Co., with a capacity of about 100,000 tons per annum, at Birmingham, Ala., was started in April, 1902. In Alabama the Central Iron & Coal Co., at Tuscaloosa, is erecting a coke blast furnace and three other stacks whose product is not expected to be available during 1902 are also under construction elsewhere in the State. The Lackawanna Steel Co. has moved its Scranton plant, comprising two small stacks, to Buffalo, N. Y., and is adding two large modern stacks. Five large stacks are under construction in Ohio. Two new

large blast furnaces for the Colorado Fuel & Iron Co., at Pueblo, Colo., are expected to be blown in by the fall of 1902. The capacity of the two new stacks is rated at 275,000 tons per annum. The new Pioneer charcoal furnace under construction at Marquette, Mich., will be in operation in the fall of 1902. With the nine blast furnaces expected to be started during 1902 and the 18 furnaces at present under construction to contribute to the output of 1903, a considerable increase in pig iron production may be expected by the end of 1903.

The returns from the census of 1900 show, according to the list of selected manufactures prepared by the Bureau of Manufactures, that the Textile industries took first place in the list with a value of product aggregating $966,924,835, but if the metallurgical industries, including iron and steel, lead, copper, and zinc, are taken together, as is the custom with textile industries, the product of the metal industries aggregates $1,194,545,506 in value for the year 1900. Among separate industries iron and steel is far in the lead. The total number of men employed was 226,161, who received $122,710,193 in wages. The rolling mills and steel works led the list with 183,023 men employed at wages aggregating $102,238,692, against 39,241 blast furnace men earning $18,484,400. A comparison of the numbers of plants operative in 1900 with those of 1890 shows the following: Including 57 plants making tin and terne plates there were in 1900, 725 operative plants, against 719 in 1890, a gain of 6 plants; 438 operative rolling mills and steel plants, as against 395, a gain of 43 plants; 223 operative blast furnaces, against 304, a loss of 81; 7 active forges and bloomeries, against 20, a loss of 13 plants for the decade. The capital invested in the 725 active establishments in 1900 aggregated $580,041,710; $122,710,193 was paid in wages; 9,544 officers and clerks were paid $12,028,811; cost of materials used for conversion was $549,127,082; miscellaneous expenses amounted to $32,570,556. The total value of the manufactured produce was $835,759,034, divided as follows: Rollings mills and steels works, $596,588,034; blast furnaces, $206,756,557; tin and terne plate, $31,892,011; and forges and bloomeries, $522,432.

The year 1902 has thus far developed no reaction from the very favorable trade conditions. The consolidation of the greatest iron ore producers, blast furnaces, and finishing works into the United States Steel Corporation, has probably more than any other one factor contributed to the steadying, both of prices and demand for iron and steel, and its settled policy of holding to the fairest range of prices in spite of the temptations formerly yielded to by smaller concerns to take advantage of restricted supply and increased demand, cannot but be of the greatest possible service to industry generally.

More than one-half of our structural steel is consumed in satisfying the demands for high bridges and structural steel work of tall buildings. The pressed steel car industry has attained to enormous proportions and demand is constantly increasing. Mr. James M. Swank, in Statistics of the American Iron Trade for 1901, states that: "It may not be generally known that our steam and trolley railroads consume in rails, cars, locomotives, bridges, buildings, and electrical machinery fully one-third of all the iron and steel we annually make. The building of steel vessels also calls for an increasingly large supply of steel plates and for steel in other forms." With increased railroad facilities

and the number of new stacks constructed during 1901, there is little foundation for the apprehension expressed so freely toward the close of the year, that large importations of iron and steel from abroad would be necessary to satisfy home demands for the crude product during 1902.

Our iron and steel exports for 1901 amounted to $102,534,575 in value, against $129,633,480 for 1900, showing a loss of $27,098,905 during the year. Our imports of iron and steel were valued at $20,394,995 during 1901, against $20,443,911 in 1900. So much of the product of pig iron was consumed at home during the year that the decline in the value of exports of iron and steel is accounted for by the decrease in pig iron shipments. The exports of pig iron during 1901 amounted to 81,211 tons, against 286,687 tons in 1900.

IRON ORE MINED AND CONSUMED IN THE UNITED STATES. (IN TONS OF 2,240 LB.)

District.	1899.	1900.	1901.
Lake Superior, shipments to furnaces	18,251,804	19,095,398	20,589,237
Southern States, shipments to furnaces	4,800,000	5,100,000	4,767,667
Other States, shipments to furnaces	2,240,000	1,758,000	3,530,575
Total mined in United States	25,291,804	25,917,398	28,887,479
Add decrease in stocks at Lake Erie docks	.....	.....	45,007
Add importations	674,082	897,792	966,950
Total	25,965,886	26,815,185	29,899,436
Deduct increase in stocks at Lake Erie docks	750,000	620,000	.....
Deduct exportation	40,665	51,460	64,703
Total consumption	25,175,221	26,073,725	29,834,733

Pig Iron.—The production of pig iron in the United States in 1901 and in previous years is given in the subjoined tables:—

PRODUCTION OF PIG IRON IN THE UNITED STATES. (*g*) (IN TONS OF 2,240 LB.)

(Includes Spiegeleisen and Ferromanganese.) Table continued on p. 380.

According to Fuel Used.	1898.	1899.	1900.	1901.
Anthracite and coke	1,203,273	1,599,552	1,677,048	1,712,527
Bituminous and coke	10,273,911	11,736,385	11,727,712	13,782,386
Charcoal	296,750	284,766	339,874	360,147
Charcoal and coke	.....	.....	44,608	23,294
Totals	11,773,934	13,620,703	13,789,242	15,878,354

Kind of Iron.	1899.		1900.		1901.	
	Tons.	%	Tons.	%	Tons.	%
Foundry and forge iron	4,213,124	30·9	4,517,437	32·8	4,541,250	28·6
Bessemer pig	8,202,778	60·2	7,943,452	57·6	9,546,798	60·4
Basic pig	985,033	7·3	1,072,376	7·8	1,448,850	9·1
Spiegeleisen and ferromanganese	219,768	1·6	255,977	1·8	291,461	1 9
Totals	13,620,708	100·0	13,789,242	100·0	15,878,354	100·0

The first report of the United States Steel Corporation confirms the great advantages claimed for the consolidation at the time it was organized in April, 1901. It has been deemed advisable to have the official year correspond with the calendar year, and this preliminary report covers only the first nine months of the corporation's existence. This period has been rather short to organize and systematize satisfactorily the large and diversified business interests in-

PRODUCTION OF PIG IRON IN THE UNITED STATES. (*g*) (IN TONS OF 2,240 LB.)

States.	1896.	1897.	1898.	1899.	1900.	1901.
Alabama	922,170	947,881	1,033,676	1,068,905	1,184,337	1,295,212
Colorado	45,104	6,562	*a* 141,010	*a* 138,880	*a* 159,204	*a* 208,409
Connecticut	10,187	8,386	6,386	10,129	10,238	8,442
Georgia	15,593	17,092	13,762	*b* 17,835	*b* 28,984	*b* 27,333
Illinois	925,239	1,117,239	1,365,896	1,442,012	1,363,383	1,596,850
Kentucky	70,660	35,899	100,724	119,019	71,562	68,462
Maryland	79,472	193,702	190,974	234,477	290,073	303,186
Massachusetts	1,873	3,284	3,661	2,476	3,310	3,396
Michigan	149,511	132,578	147,640	134,443	163,712	170,762
Minnesota	(*f*)	(*f*)	(*f*)	(*f*)	(*f*)	(*f*)
Missouri	12,548	23,883	(*c*)	(*c*)	(*c*)	(*c*)
New Jersey	59,153	95,696	101,681	127,598	170,362	155,746
New York	206,075	243,304	238,011	264,346	292,827	283,662
North Carolina	2,151	.....	.....	(*e*)	(*e*)	(*e*)
Ohio	1,196,326	1,372,889	1,996,358	2,378,212	2,470,911	3,326,425
Pennsylvania	4,024,166	4,681,634	5,537,882	6,558,878	6,365,935	7,343,257
Tennessee	248,338	272,190	263,489	346,166	362,190	337,139
Texas	1,221	6,175	5,178	5,803	10,150	2,273
Virginia	386,277	307,610	283,274	365,491	490,617	448,662
West Virginia	108,569	132,907	192,699	187,558	166,758	166,547
Wisconsin	*d* 158,484	*d* 103,909	*d* 172,781	*d* 203,175	*d* 184,794	*d* 207,551
Totals	8,623,127	9,652,680	11,773,984	13,620,703	13,789,342	15,878,354

(*a*) Production of Missouri, and Washington for 1901, included. (*b*) Production of North Carolina included. (*c*) Production included in Colorado figures. (*d*) Production of Minnesota included. (*e*) Production included in Georgia figures. (*f*) Production included in Wisconsin figures. (*g*) Statistics furnished by James M. Swank, of the American Iron and Steel Association.

volved, yet the results even in this time have been more than gratifying. Great economies have resulted from the harmonious co-operation in the departments of ore mining, coal mining and lake transportation. The most pronounced benefits, however, have resulted from the manufacture of the various products at the point most favorable to the production, together with the greater efficiency of the work which has resulted from the free interchange of news and experiences of all engaged in the various branches of manufacture. The net earnings of the corporation for the nine months ending December 31, 1901, after deducting current renewals and ordinary repairs for maintenance of plants, amounted to $84,779,298, from which the following amounts were charged: $2,250,000 to set aside as a sinking fund to retire the bonds of the corporation and subsidiary companies; $11,400,000 for nine months' interest on the bonds of the corporation; $26,750,000, dividends on the preferred stock at 7% per annum; $15,227,000 dividends on the common stock at 4% per annum, making a total of over $53,000,000. Nearly $10,000,000 was set aside in various reserve funds to cover exhaustion of ore supplies, depreciation of machinery and special enlargements. The above shows individual earnings of over $19,000,000 for the nine months' operations. A balance sheet showing the assets and liabilities at November 31, 1901, is included in the report in place of a detailed profit and loss statement, which latter cannot be given satisfactorily until absolute uniformity in the accounting systems of all the companies has been established. In brief this report will be found on page 381.

It is stated that the actual business booked of which shipment is being called for faster than it can be supplied, amounts to more than half the total combined annual capacity of all the companies and the heavier products as rails, billets, plates and structural shapes are sold up to the productive capacity of the mills until nearly the end of the year. Despite the great demand for products the prices have not been advanced, and the firm stand of the corporation for stability of prices, both of raw and finished products, has had a most assuring

effect on the trade. The stockholders of the United States Steel Corporation number about 60,000.

Assets.—Property		$1,437,494,862·58
Deferred charges to profit and loss, exploration, development, etc		8,256,774·09
Investments outside of real estate		429,613·25
Current assets—Inventories	$95,603,997·57	
Stocks, bonds, securities of outside companies	7,251,329·45	
Accounts receivable	45,269,453·19	
Bills receivable	2,821,463·55	
Cash	55,315,527·99	206,261,771·75
Total		$1,647,443,021·62
Liabilities.—Capital stock, U. S. Steel Corporation:		
Common	$508,212,543·70	
Preferred	510,173,778·40	1,018,386,322·10
Capital stock, subsidiary companies not held by U. S. Steel Corp. (par value):		
Common	$365,436·38	
Preferred	293,300·00	
L. S. consolidated mines sub. companies	113,189·43	771,925·81
Bonded and Debenture Department:		
U. S. Steel Corporation bonds	$303,450,000·00	
Funded dept. sub-companies held by public	59,349,838·65	
Debenture script	41,844·57	362,841,683·42
Mortgages and purchase money obligations (sub-companies):		
Mortgages	$3,457,037·55	
Purchase money obligation	15,610,754·03	19,067,791·58
Current Liabilities:		
Pay-rolls and accounts payable	$22,228,343·60	
Bills and loans payable (sub-companies)	12,653,744·27	
Special deposits due	5,435,342·15	
Accrued interest and unpresented coupons	4,870,410·16	
Common dividend No. 2, payable 12-20-01	5,081,790·00	50,269,630·18
Contingent liabilities		525,398·67
Sinking fund and depreciation reserves		21,236,040·54
Surplus of U. S. Steel Corporation and sub-companies		174,344,229·32
Total		$1,647,443,021·62

Iron Ore.—The production of iron ore in the United States in 1901 amounted to 28,887,479 long tons, against 27,553,161 long tons in 1900. Minnesota, which is now the leading iron ore State, registered the largest increase, producing 11,109,537 long tons in 1901, against 9,834,399 tons in 1900, an increase amounting to 1,275,138 long tons.

The total imports in 1901 were 966,950 tons, against 897,831 tons in 1900. Cuba in 1901 supplied 522,723 long tons, against 419,632 long tons in 1900, the principal shippers being the Juragua Iron Co., Ltd., the Spanish-American Iron Co., and the Cuban Steel Ore Co., the latter shipping for its first year of business, 17,651 long tons. The furnaces on Puget Sound, Washington, received some shipments from British Columbia and Alaska, and the balance of the importations came from Spain and Newfoundland. The exports of iron ore for the year 1901 were but 64,703 long tons, against 51,460 long tons for 1900.

While the production of pig iron in the United States showed a very considerable increase over 1900, the consumption of pig iron increased more rapidly, amounting to 16,228,796, as shown by the subjoined table:—

CONSUMPTION OF PIG IRON IN THE UNITED STATES. (IN LONG TONS.)

	1900.	1901.		1900.	1901.
Domestic production	13,789,245	15,878,354	Exports	286,815	81,211
Imported	52,565	62,930	Stocks unsold, Dec. 31	442,370	73,647
Stocks unsold, Jan. 1	68,309	442,370	Total deductions	732,835	154,858
Total supplies	13,910,116	16,383,654	Consumption	13,177,281	16,228,796

Blast Furnace Production.—The furnaces in blast on January 1, 1902, and January 1, 1901, were 264 and 233, respectively, the average weekly production during the year being 304,181 tons, against an average during 1900 of 262,304. The average number of furnaces in operation during 1901 was 254, against 256 for the previous year, the average production per furnace during 1901 being 62,513 tons, against 53,864 tons for 1900. A detailed account of the progress in blast furnace work will be found elsewhere in this section under the caption "Modern Improvements in the Manufacture of Pig Iron," by John Birkinbine.

Steel.—The production of steel in the United States in 1901 is given in the subjoined table:—

PRODUCTION OF STEEL IN THE UNITED STATES. (IN TONS OF 2,240 LB.)

Kinds.	1896.	1897.	1898.	1899	1900.	1901.
Bessemer	3,919,906	5,475,315	6,609,017	7,586,354	6,684,770	8,713,302
Open-hearth	1,298,700	1,631,843	2,230,292	2,947,316	3,402,552	4,656,309
Crucible	62,500	65,600	89,747	128,500	131,250	103,984
Miscellaneous	900	1,750	3,801			
Total tons	5,582,606	7,174,508	8,932,857	10,662,170	10,218,572	13,473,595
Total metric tons	5,671,928	7,289,300	9,075,783	10,832,765	10,382,069	13,689,945

The production of Bessemer steel in the United States in 1901 was 8,713,302 tons, against 6,684,770 tons in 1900, an increase of 2,028,532 tons during 1901. Of the total production, Pennsylvania furnished 4,293,439 long tons; Ohio, 2,154,846 long tons; and Illinois, 1,324,217 long tons; these three States furnishing together 89·2% of the total product. Of the production in 1901, 6,764 tons were steel castings, against 6,467 tons for 1900. During 1901, two Roberts-Bessemer plants, and seven Tropenas plants were employed in the manufacture of steel castings. No Clapp-Griffiths plants were operated. The production of Bessemer steel rails by the producers of Bessemer steel ingots in 1901 was 2,836,273 long tons, against 2,361,921 long tons for 1900, a gain of 474,352 long tons during the year. During 1901, 34,543 tons of Bessemer rails were made from purchased blooms, and from re-rolled and renewed Bessemer steel rails, making the total Bessemer steel rails produced 2,870,816 long tons. The exports of steel rails in 1901 was 318,055 long tons, against 356,245 long tons in 1900, showing a loss for the year of 38,150 long tons. The use of heavier rail sections diminished in 1901, and medium weight rails correspondingly increased. The division of steel rails, according to the weight per yard, is separately reported by the American Iron & Steel Association, in the subjoined table:—

Weight per Yard.	1899.	1900.	1901.
	%	%	%
Heavy rails, over 85 lb.	25·9	25·5	17·1
Medium rails, between 45 lb. and 85 lb.	68·3	68·0	77·4
Light rails, less than 45 lb.	5·8	6·5	5·5
Total	100·0	100·0	100·0

The total of 2,093 long tons of steel rails produced by the open-hearth process in 1901 is larger than any previous record for the United States. Of the total

output of steel rails during the year, Pennsylvania produced slightly less than one-half. Adding the 1,730 tons of iron rails produced in 1901 to the total of steel rails by the open-hearth process (2,093 long tons) and the total Bessemer steel rails (2,870,816 long tons), the grand total of steel rails produced during the year amounted to 2,874,639 long tons.

The subjoined table shows the production of rails as compared with that of Bessemer steel ingots, for the past six years:—

Year.	Tons Ingots	Tons Rails.	Per Cent.	Year.	Tons Ingots	Tons Rails.	Per Cent.
1896	3,919,906	1,102,892	28·1	1899	7,586,354	a 2,240,767	29·5
1897	5,475,315	1,614,899	29·4	1900	6,684,770	a 2,361,921	35·3
1898	6,609,017	1,955,427	29·6	1901	8,713,902	a 2,836,273	32·5

(a) Not including rails made from purchased blooms or re-rolled rails.

The production of open-hearth steel in 1901, including direct steel castings, was 4,656,309 long tons, against 3,398,135 long tons in 1900, an increase of 1,258,174 tons, or over 37%; the basic process steel amounted to 3,618,993 long tons, and the acid process steel to 1,037,316 long tons. The production of open-hearth steel in 1901 was derived from 90 works in 14 States. Neither Maryland, Kentucky, Michigan, nor Minnesota made open-hearth steel during 1901, although all of them were producers in 1900, and Rhode Island made open-hearth steel during 1901 for the first year of production. The total production of open-hearth steel castings included above amounted to 301,622 long tons during 1901, of which 94,941 tons were made by the basic process and 206,681 tons by the acid process. The production of crucible steel in the United States during 1901 amounted to 98,513 long tons, against 100,562 tons in 1900.

Tin Plate.—The production in long tons of finished tin plate (including dipping plants) is given by James M. Swank as follows:—

Year.	Tons.	Year.	Tons.	Year.	Tons.
1893	55,182	1896	160,362	1899	360,875
1894	74,260	1897	256,598	1900	302,665
1895	113,666	1898	328,915	1901	399,291

Changes in Iron and Steel Metallurgy.—The long expected decision of the United States Supreme Court in Jones against the Cambria Iron Works, has been rendered in favor of the Jones mixer, the patents of which are now among the assets of the United States Steel Corporation. The decision was sweeping, virtually rendering the use of all mixers of any size subject to the rights of the Jones patents. Interests connected with the Lackawanna Iron & Steel Co. have purchased the controlling interest in the Continuous Metal Refining Co., which owns the Talbot patents. The Talbot process has been in use at the Pencoyd Iron Works, in Pencoyd, Pa., for about two years. In the early part of 1901 a very complete bibliography of "Steel Works Analysis," prepared by Harry Brearley, was published by the *Chemical News*. Experiments for the production of steel by electricity carried on at Gysinge, Sweden, are claimed to be so successful that the present plant, said to produce 25,000 lb. of high-grade steel daily, is to be moved to the Dalalfuen river, where a large water power is to be utilized.

The improvements in pig iron manufacture are exhaustively treated elsewhere in this section by John Birkinbine, under the caption "Modern Improvements in the Manufacture of Pig Iron."

The Iron Markets in 1901.

Although 1901 opened with a rather discouraging outlook for the American iron trade, the conditions improved rapidly in the early months, and to such an extent that the year's business was extremely profitable to the manufacturers. The demand for iron and steel was sufficient to keep the furnaces and mills running at their full capacity, resulting in an output that exceeded all records. The general level of prices was below that of 1900, but the trend was upward from the beginning, and there were no such violent fluctuations to unsettle the market as characterized that year.

Alabama.—The records for the year show an increase in shipments of iron and healthy conditions prevailing in the trade. Prospects were doubtful in the first quarter, but the spring months brought a better demand, which continued for the remainder of the year. At the close, the market was firm and strong, with good quotations and plenty of orders. Manufacturers are looking to the future with confidence and some are preparing to increase the output of their plants.

Chicago, Ill.—The pig iron consumption in this district increased fully 10% over previous years. Prices were steady; at no time was the variation greater than $1 per ton. Trade was hampered by the inability of the railway companies to handle the traffic, and the year closed with no improvement in this respect. The outlook for the future is encouraging, although some dealers and manufacturers incline to the belief that a slump in prices will come before the end of 1902. The consumption of pig iron in the Chicago district in 1901 is estimated at 2,250,000 tons.

AVERAGE MONTHLY PRICES OF IRON AND STEEL AT CHICAGO DURING 1901.

Month.	Local Coke No. 2.	Lake Superior Charcoal.	Ohio Strong Soft No. 1.	Southern Coke No. 2.	Steel Plates.	Steel Rails.
	Long Tons.	Long Tons.	Long Tons.	Long Tons.	Pounds.	Pounds.
January	$14·75	$19·00	$16·125	$14·50	$1·55	$26·00
February	14·25	17·50	16·00	14·15	.....	26·00
March	15·25	17·50	16·50	15·00	.....	26·00
April	15·50	18·00	16·50	15·40	1·65	26·00
May	15·50	17·50	16·50	14·90	1·65	28·00
June	15·00	17·00	16·25	14·30	1·65	28·00
July	15·00	17·00	16·00	14·15	1·65	28·00
August	15·00	17·00	16·00	14·15	1·65	28·00
September	15·00	17·00	16·00	14·15	1·65	28·00
October	14·75	17·00	16·50	14·40	1·65	28·00
November	14·87	17·50	17·125	14·90	1·65	28·00
December	15·50	18·00	17·50	15·15	1·65	28·00
Average for year 1901	$15·00	$17·50	$16·50	$14·60	$1·63	$27·33

Cleveland, Ohio.—The production of pig iron in this section in 1901 was unprecedented, and there was hardly a time that the demand did not exceed the output. Prices were steady throughout the year. Large sales of material, especially steel, were made on contracts covering the output of the furnaces for a period of six to fifteen months.

IRON ORE SHIPMENTS FROM UPPER LAKE PORTS. (IN TONS OF 2,240 LB.)

Ports.	1899.	1900.	1901.	Ports.	1899.	1900.	1901.
Escanaba	3,720,218	3,436,734	4,022,668	Duluth	3,509,965	3,688,986	3,497,955
Marquette	2,733,596	2,661,661	2,354,284				
Ashland	2,703,447	2,633,687	2,886,252	Total by Lake	17,901,358	18,570,315	20,157,522
Two Harbors	3,973,733	4,007,294	5,018,197	Rail shipments	350,446	489,078	431,715
Gladstone	381,457	418,354	117,089				
Superior	878,942	1,522,899	2,321,077	Total shipments	18,251,804	19,059,393	20,589,237

SHIPMENTS OF LAKE SUPERIOR IRON ORE BY RANGES. (IN TONS OF 2,240 LB.)

Year.	Marquette.	Menominee	Gogebic.	Vermilion.	Mesabi.	Michipicoten. (Can da.)	Totals.
1897	2,715,035	1,937,913	2,258,236	1,278,481	4,280,873		12,469,538
1898	3,195,039	2,527,274	2,498,462	1,265,142	4,613,766		14,029,683
1899	3,737,010	3,301,052	2,795,856	1,771,502	6,626,384		18,251,804
1900	3,457,522	3,261,221	2,875,295	1,655,820	7,809,535	62,000	19,181,393
1901	3,254,680	3,605,449	2,938,155	1,786,063	9,004,890	160,000	20,749,237
Totals from opening	62,847,473	37,021,428	34,154,790	16,977,243	40,404,967	222,000	192,227,901

IRON ORE RECEIPTS AND STOCKS AT LAKE ERIE PORTS. (IN TONS OF 2,240 LB.)

Ports.	Receipts at Ports.				Stock on Docks Dec. 1.			
	1898.	1899.	1900.	1901.	1898.	1899.	1900.	1901.
Toledo	414,012	792,348	645,147	798,298	146,568	186,422	242,375	254,196
Sandusky	136,300	87,499	154,542	33,017	48,500	23,184	95,111	47,384
Huron	126,755	263,600	321,914	431,311	139,962	164,480	211,377	231,501
Lorain	536,086	1,112,946	1,090,235	721,662	324,084	337,822	251,838	195,863
Cleveland	2,645,318	3,223,582	3,376,644	3,831,060	1,175,970	1,200,806	1,337,445	1,378,060
Fairport	912,879	1,241,013	1,085,554	1,181,776	719,794	692,147	611,717	710,590
Ashtabula	2,684,563	3,341,526	3,700,486	3,981,170	1,732,671	1,902,598	1,811,459	1,769,145
Conneaut	1,404,169	2,320,696	2,536,631	3,181,019	288,101	468,808	630,514	604,106
Erie	1,092,364	1,309,961	1,240,715	1,379,377	489,167	361,335	480,734	470,718
Buffalo, Tonawanda	1,075,975	1,530,016	1,616,919	1,475,386	121,630	192,681	232,109	198,100
Totals	11,028,321	15,222,187	15,797,787	17,014,076	5,136,407	5,530,283	5,904,670	5,859,663

Pittsburg.—The past year was more satisfactory to the iron and steel interests than 1900 or 1899, despite the big strike of steel workers, which curtailed the production of the United States Steel Corporation by thousands of tons. While prices did not reach as high a point as in the preceding two years, the output of mills and furnaces was much larger. The capacity of many plants was increased and new works were built, but at no time was the production in excess of the demand. The year opened with Bessemer iron considerably depressed in price and small sales were made as low as $12·25 at Valley furnace. The buying movement was started by the Carnegie Steel Co., which contracted for 150,000 tons of Bessemer pig at $12·50, and other sales were negotiated, bringing the January total up to 215,000 tons. Bessemer billets remained at the fixed price of $19·75 per ton until April, when the price was advanced to $24. There was a strong demand for sheet and tie bars, and the quotations ruled high throughout the first half of the year, sales having been made at $28 and $29 per ton. Tank plates sold at $1·40, but soon were advanced $2 per ton, and by another $2 in April. Rails, standard sections, sold for $26 per ton until April, when the price was raised to $28, at which figure large contracts were made that practically fixed the prices, not only for the remainder of 1901, but also for 1902. The demand for light rails in the latter part of the year was without parallel, and high prices

were paid for fair deliveries. Sheets, No. 28 gauge, brought 2·95c. in January, advancing to 3·35c. in February, where they remained until July 1, when a reduction to 3c. was made for large lots. Bessemer pig advanced to $14 in February, with the increasing demand, and during the next two months prices reached $16@$16·25. In July the United States Steel Corporation established a central pig iron purchasing department, through which all iron for the constituent companies is bought. For the remainder of the year prices ranged from $15·50 to $16; in December prompt deliveries commanded a premium over these figures, owing to a serious shortage of coke which forced many of the furnaces to bank. Sheet bars in the latter half of the year were strong and sales were made for prompt deliveries as high as $30 and $31 per ton. Tank plates from April to December remained at 1·60c., with a good market. The great need of the Pittsburg district is increased shipping facilities. The freight congestion is becoming worse each year, and until relief is had the proper operation of furnaces and mills will be greatly hampered.

DECEMBER PRICES FOR IRON AND STEEL AT PITTSBURG.

(Per Long Ton.)

	1899.	1900.	1901.		1899.	1900.	1901.
Bessemer	$25·00	$13·90	$16·75	Billet ends	$24·00	$18·00	(a)
No. 1 Foundry	24·00	13·00	16·75	Heavy melting steel	.....	.....	$17·50
No. 2 Foundry	23·25	12·50	16·25	No. 1 wrought scrap	24·00	17·00	17·00
Basic iron	.....	.....	15·75	Steel rails	37·00	26·00	28·00
Gray forge	21·50	13·25	15·00	Iron bars (b)	2·15	1.40	1·50
White iron	20·00	.....	(a)	Steel bars (b)	.....	.....	1·50
Mottled iron	20·50	13·50	(a)	Cut nails (b)	2·50	2·05	2 05
Silvery, No. 1	27·00	16·00	(a)	Wire nails (b)	2·95	2·20	2·05
Charcoal, No. 1 Foundry	27·00	16·00	(a)	Furnace coke at ovens	3·00	1·75	2·25
No. 2 Foundry	26·00	15·50	(a)	Ferromanganese, 80%	100·00	62·50	52·50
Cold blast	28·00	16·50	(a)	Old iron rails	30·00	22·00	21·50
Warm blast	27·00	16·00	(a)	Old steel rails	23·00	17·00	16·50
Muck bar	33·00	24·00	29·00	Sheets, No. 28 gauge (b)	.....	.....	3·20
Billets	37·00	19·75	28·00	Tank plate (b)	.....	.....	1·60

(a) No quotations available as quantities used in Pittsburg are comparatively insignificant. (b) Cents per pound.

Production of Pig Iron and Steel in the World.

The total production of pig iron for the world in 1901 was 40,785,605 metric tons, an increase of 587,011 metric tons over that of 1900, while the production of steel amounted to 31,018,490 metric tons, an increase amounting to 3,040,861 metric tons for the year. A comparison of the relative production of pig iron and steel during the past few years shows that annually greater proportions of pig iron are being converted into steel, due to the demands for structural purposes, as well as to decreases in the cost of manufacture. Large quantities of steel are absorbed for the production of cars and structural steel. The prosperity in iron and steel was greatest in the United States in 1901, the production of both in the United States being more than Germany and Great Britain combined. Germany and the other European countries suffered greatly from depression in the iron and steel trades during the year. The statistical diagram which is given later in this section, shows very clearly the relative position occupied by the products of iron and steel during the past 25 years. Of the world's production of pig iron in 1901, the United States made 39·5%, the United Kingdom 19·3%, and Germany 19·2%, a total of 78·0% of the entire output for the year. The

percentage of the world's production of steel for 1901 was for the United States 44·1%, United Kingdom 16·3%, Germany 20·6%, a total of 81·0% of the world's supply.

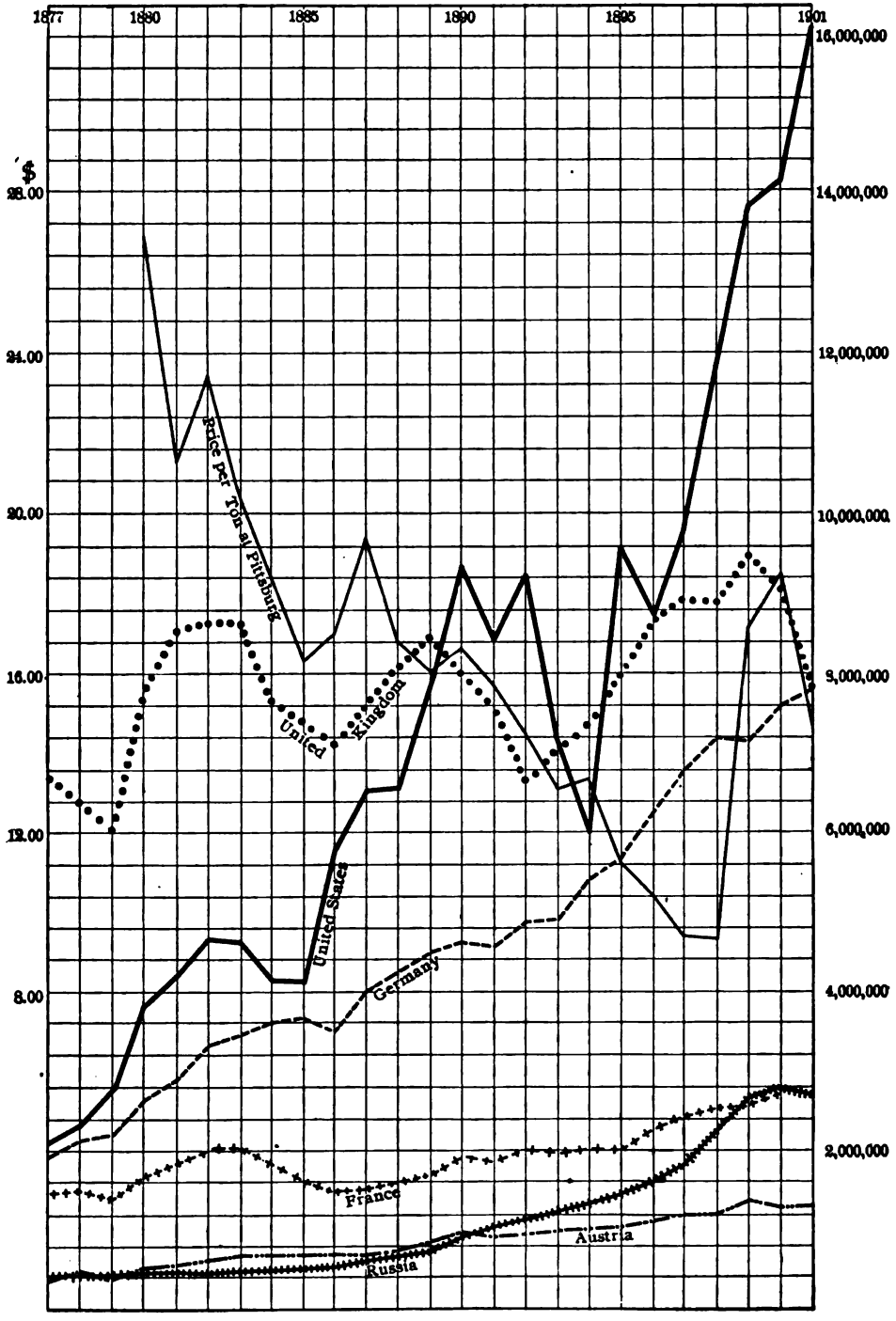
Belgium.—The total production of pig iron in 1901 was 765,420 metric tons, against 1,145,654 metric tons in 1900, showing a decrease of 380,234 tons. These totals include foundry, forge, and steel pig. The total production of steel in 1901 was 526,670 tons, against 655,199 tons in 1900, a decrease of 128,529 tons. While there was a considerable falling off in the production of various grades of pig iron during 1901, the production of finished iron showed some progress, but this was offset by a decline in the output of steel. The number of furnaces in blast on December 31, 1901, was 26, against 31 for the corresponding date of 1900.

Canada.—The production of pig iron during 1901 was 244,976 long tons, against 86,900 long tons in 1900, a very considerable increase during the year. Of the total output of pig iron, 228,893 long tons were coke iron, and 16,083 long tons were charcoal iron. The production of Bessemer pig iron was 29,577 long tons. No spiegel iron nor ferromanganese was produced during the year. The annual consumption of pig iron and steel and their products in Canada is between 800,000 and 820,000 long tons. The exports of iron ore during 1901 amounted to 306,199 short tons. On December 31, 1901, there were 12 completed furnaces and four more in course of construction, with a total aggregate capacity of nearly 1,100,000 long tons. The investment of capital in Sydney, Hamilton, Deseronta, Midland, New Glascow, Radnor, Drummondville, and Ferrona amounts to $24,500,000 which will be increased to $35,000,000 with the completion of a new furnace early in 1902. The Lake Superior Power Co., at Sault Ste. Marie, Ont., is building an extensive plant for making pig iron, steel, and steel rails, the latter the first plant of its kind to be erected in Canada. Of the four furnaces which were erected during 1901, by the Dominion Iron & Steel Co., at Sydney, Cape Breton, N. S., three were put into blast during the latter part of the year, and the fourth in January, 1902.

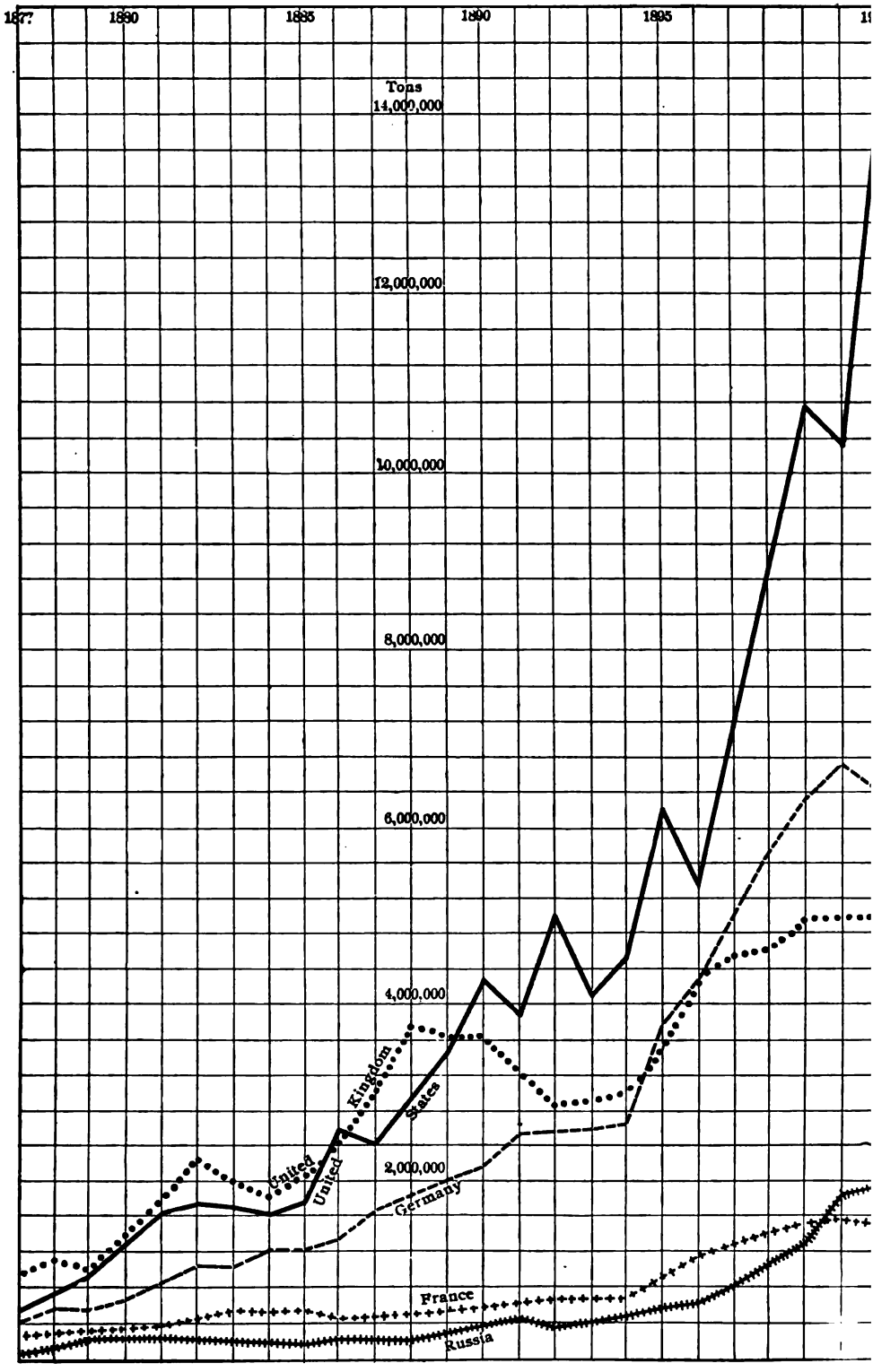
France.—The production of pig iron in 1901 was 2,400,240 metric tons, against 2,714,298 metric tons in 1900, a decrease of 314,058 metric tons for the year. The production of all kinds of steel during 1901 amounted to 1,465,071 metric tons (against 1,565,164 tons in 1900), which was distributed as follows: Bessemer steel ingots, 860,425 tons; open-hearth steel ingots, 604,646 tons. There was a decided falling off in all branches of the iron and steel industry during the year.

Germany.—The production of pig iron in Germany, including Luxemburg, is reported by the Association of German Iron and Steel Makers in the following table:—

Description.	1899.		1900.		1901.		Changes.
	Metric Tons.	%	Metric Tons.	%	Metric Tons.	%	Metric Tons.
Foundry iron	1,424,732	17·7	1,487,929	17·8	1,512,107	19·4	Inc. 24,198
Forge iron	1,668,571	20·7	1,587,194	19·0	1,356,794	17·4	Dec. 230,400
Bessemer pig	516,950	6·5	495,790	5·9	464,036	6·0	Dec. 31,754
Thomas (basic) pig	4,424,052	55·1	4,780,829	57·3	4,452,950	57·2	Dec. 327,879
Totals	8,029,305	100·0	8,351,742	100·0	7,785,887	100·0	Dec. 734,653



THE WORLD'S PRODUCTION OF PIG IRON IN METRIC TONS.



THE WORLD'S PRODUCTION OF STEEL
IN METRIC TONS

PRODUCTION OF PIG IRON AND STEEL IN THE PRINCIPAL COUNTRIES. (IN METRIC TONS.)

Year.	Austria-Hungary.		Belgium.		Canada.	France.		Germany.	
	Pig Iron.	Steel.	Pig Iron.	Steel.	Pig Iron.	Pig Iron.	Steel.	Pig Iron.	Steel.
1897	1,165,188	553,000	1,095,087	527,617	49,497	2,484,191	994,891	6,864,405	5,091,294
1898	1,286,388	605,500	979,755	567 728	69,248	2,525,100	1,174,000	7,215,927	5,734,307
1899	1,323,999	1,127,104	1,036,185	729,820	95,582	2,578,400	1,240,000	7,160,208	6,290,484
1900	1,311,949	1,145,654	1,161,180	655,199	87,612	2,714,298	1,565,164	7,549,655	6,645,869
1901	a1,300,000	a 1,142,000	765,420	526,670	948,696	2,400,240	1,465,071	7,835,204	6,394,222

Year.	Italy.		Russia.		Spain.		Sweden.	
	Pig Iron.	Steel.	Pig Iron.	Steel.	Pig Iron.	Steel.	Pig Iron.	Steel.
1897	8,398	63,940	1,880,135	821,000	298,841	121,100	538,197	268,300
1898	12,387	87,467	2,241,290	1,095,000	229,754	112,605	531,766	263,700
1899	19,218	106,501	2,708,749	1,321,328	266,385	117,650	497,727	273,454
1900	23,990	115,857	2,895,636	1,530,260	290,788	144,355	525,968	300,536
1901	a 25,000	a120,000	a 2,750,000	a 1,815,000	294,118	122,954	528,375	269,897

Year.	United Kingdom.		United States.		All Other Countries.		Totals.	
	Pig Iron.	Steel.	Pig Iron.	Steel.	Pig Iron. (a)	Steel. (a)	Pig Iron.	Steel.
1897	8,930,066	4,559,736	9,807,123	7,289,300	450,000	310,000	33,508,093	20,610,178
1898	8,819,968	4,639,042	11,962,317	9,075,783	545,000	355,000	36,418,900	23,710,432
1899	9,572,178	5,080,000	13,838,634	10,832,765	625,000	400,000	39,722,260	27,520,966
1900	9,003,046	5,130,800	14,009,870	10,382,069	625,000	400,000	40,196,892	28,315,798
1901	7,886,019	5,080,000	16,132,408	13,689,173	635,000	405,000	40,800,880	31,029,987

(a) Estimated.

For the nine years previous to 1901 Germany had enjoyed a gain in both iron and steel production with each succeeding year, but the financial depression of 1901 made it impossible for the home market to absorb even the restricted production of the furnaces, and during the closing months of the year German pig was offered at very low prices on the English market. During 1901, 92·7% of the entire steel output was made by the basic process. The fact that over 80% of the pig iron made during 1901 was converted into steel shows the increase in its use and the decreased use of wrought iron.

The production of steel in Germany, as reported by the Association of German Iron and Steel Makers, is given in the subjoined table:—

	1899.		1900.		1901.	
	Metric Tons.	%	Metric Tons.	%	Metric Tons.	%
Basic converter	3,973,225	63·2	.....	.....	3,975,070	62·1
Basic open-hearth	1,693,895	26·9	.....	.....	1,886,536	29·5
Basic castings (direct)	.....	.....	.....	.....	67,576	1·0
Total basic	5,667,050	90·1	6,223,417	.....	5,929,182	92·6
Bessemer	623,384	9·9	.....	.....	299,816	4·6
Acid open-hearth			.....	.....	125,590	2·8
Acid castings (direct)					39,694	.....
Totals	6,290,434	100·0	6,645,869	.....	6,394,222	100·0

The German methods of classification in their statistical records are so different from those in general use that correct reports are difficult to ascertain. Spiegel iron is included with forge iron, and while the total production of steel pig for the year is given as 4,916,986 metric tons, the total production of steel shows that more than 80% of the total pig iron production was absorbed in steel making. The highest proportion of basic pig was made from the minette ores of Luxemburg, while about 75% of the Bessemer pig came from the Rhine district.

Mexico.—The Compañia Fundidora de Fierro y Acero de Monterey was organized in May, 1900, with a capital of $10,000,000 to operate the iron mines on Carrizal Mountain, on the line of the Mexican National Railroad, and at Monclova, on the Mexican International Railroad. Two of the Carrizal Mountain mines are large enough for present needs, and the ore is being conveyed by two Bleichert tramways carrying about 1,000 tons daily from the mines to the loading terminal of the branch railway, about 5 miles from Golondrina station on the main line of the Mexican National Railroad. The ores of the various mines owned by the company supply magnetite, hematite, or brown hematite, all of good quality, and comprise the only deposits of Bessemer iron known to exist in the Republic. Manganese ores varying from 40 to 55% of metallic manganese and low in phosphorus are readily obtainable in the vicinity, and limestone of an exceptional quality is found in enormous quantity close to Monterey. The Laredo coal field of 30,000 acres is owned by the company, and it also owns in part the coal fields at Barroteran, which are suitable for blast furnace coke. The plant at Monterey comprises one large blast furnace and three 35-ton open-hearth steel furnaces, all equipped with electric charging and carrying machinery. Besides foundry, machine shop, blooming mill, etc. The plant is equipped to manufacture steel rails, beams and shapes, billets and bars, pig iron and castings, and has a gross capacity of about 128,000 tons per annum.

Norway.—The Dunderland Iron Ore Co., Ltd., capitalized at $10,000,000, has acquired from the Norwegian Government extensive ore beds about 18 miles inland from Mo, on the Ronen Fjord, in the North Sea. It is estimated that 50,000,000 tons of iron ore, bearing 40% iron, are available in one deposit. An electric plant will be erected after plans of Turrettini, the well-known Swiss hydraulic engineer, about midway between the mine and tidewater, where a waterfall 112 ft. high, which will yield from 10,000 to 15,000 H.P., will be utilized by Edison's electric concentrator process. A railroad will be built from mine to tidewater, and the entire equipment will be from American factories. The iron ore will be crushed, passed through the Edison magnetic separator, and then made into briquettes for the blast furnace.

Russia.—The complete figures for the production of iron and steel in Russia are not available at the time of publication, but from the data at hand, it is evident that the production of both commodities for 1901 will be slightly less than for 1900, which is officially reported at 2,895,636 metric tons for pig iron, and 1,830,260 metric tons of steel.

Spain.—The production of iron ore and iron and steel products which is usually reported by the *Revista Minera* in advance of the Government report, has not appeared at the time of publication this year. The production of iron ore in 1900 amounted to 8,840,246 metric tons. The exports of iron ore during

1901 were 6,637,613 metric tons, as compared with 7,823,270 metric tons in the previous year, which shows a decrease of 1,185,657 metric tons. The products of iron and steel during 1899 and 1900 are given in the subjoined table:—

	1899.	1900.
Pig iron	295,840	294,118
Wrought, or puddled iron	66,568	65,045
Bessemer steel ingots	68,300	91,586
Open-hearth ingots	49,350	59,048
Finished iron and steel	173,568	212,121

The amount in metric tons and the destination of the exports of iron ore from Spain for the past five years are given in the subjoined table:—

Destination.	1897.	1898.	1899.	1900.	1901.
Great Britain	5,091,057	4,748,557	6,224,229	5,489,323	(a)
Germany	1,058,694	1,193,924	1,544,449	1,441,128	(a)
France	435,972	309,424	443,818	450,746	(a)
Belgium	224,776	201,693	254,860	247,351	(a)
United States	59,243	5,792	132,422	195,964	(a)
Other countries	14,876	8,670	13,359	8,758	(a)
Totals	6,884,588	6,558,060	8,613,137	7,823,270	6,637,613

(a) Statistics not available at time of publication.

Sweden.—(By Richard Akerman.)—The following iron and steel products of Sweden during 1901 were reported direct to THE MINERAL INDUSTRY by the General Director of the Official Mineral Statistics of Sweden. The figures are in metric tons: Iron ore, 2,795,160; pig iron, 528,375; steel blooms produced from pig iron in charcoal hearths, 164,850; Bessemer steel ingots and castings, 77,231; crucible steel ingots and castings, 1,088; open-hearth steel ingots and castings, 190,877; blister steel, 701; bar iron and steel, 152,183; nail and wire rods, band iron and steel, 89,135; otherwise shaped iron and steel in bars, 6,282; plates (sheets not included), 13,856; tube-blocks, hollow blooms, and billets, 14,333. The number of furnaces in blast during the year was 139, the average daily product per furnace being 13·96 metric tons, the average time each furnace was in blast was 272 days. The exports of steel and iron products from Sweden during 1901 are elsewhere reported in metric tons as: Iron ores, 1,761,000; pig iron, 84,600; charcoal blooms, 18,900; steel ingots, 5,900; bar iron and steel, 142,100.

Switzerland.—It is reported that electric smelting for iron and steel is to be inaugurated on a large scale during 1902, near Meiringen, in the Bernese Oberland, and that the State has given a concession for the working of an outcrop of hematite which is 7 ft. in thickness for a distance of two miles in length. 60,000 H. P. is to be utilized from a water-power in the vicinity, and the ore will be transported to Innerkirchen, in the valley below, by means of an aërial tramway. Lack of fuel for smelting has heretofore restricted the development of metallurgical industries in Switzerland.

United Kingdom.—While the British and American iron and steel trades have heretofore customarily paralleled each other in progress, during 1901 the United States exceeded all previous records in production, while the United Kingdom produced but 7,886,019 metric tons of pig iron, against 9,003,046

metric tons during 1900, a decrease of 1,117,027 metric tons for the year. The production of steel for 1901 was 5,080,000 metric tons, against 5,130,800 metric tons for 1900, a decrease of but 50,800 tons, which did not compare with the decrease in pig iron production. The home consumption of pig iron and steel showed little change, the decrease in both products being due to increase of stocks at the close of the year (a total of about 65,000 tons being on hand) and decreased exports to Russia and Germany, owing to the financial depression existing in those countries. During 1901 there was a considerable fall in prices of pig iron; Scotch pig at the opening sold for at about $14·50, while at the close of the year the price fell to about $11·50; Cleveland pig fell from $12 at the opening to $10·25 at the close of the year; while hematite or Bessemer pig iron droped from $15·25 to $13·25 per ton. The prices of finished material decreased accordingly. Iron and steel bars decreased in price about $6 during the year; sheets about $5; steel rails and ship plates about $2·50. During 1901, 55 blast furnaces suspended operations.

The production of steel in the United Kingdom is detailed in the subjoined table:—

Variety.	1898.	1899.	1900.	1901.
	Long Tons.	Long Tons.	Long Tons.	Long Tons.
Acid steel	3,845,764	4,043,259	(a) 4,328,399	4,063,444
Basic steel	720,222	812,066	(a) 821,601	841,000
Total open-hearth	2,806,600	3,030,251	3,156,050	3,297,791
Total Bessemer	1,759,386	1,825,074	1,745,004	1,606,653
Total crucible	(a) 100,000	(a) 144,325	(a) 148,946	(a) 95,956
Total steel	(a) 4,665,986	5,000,000	5,050,000	5,000,000

(a) Estimated.

The chief descriptions of finished Bessemer steel, which are reported to the association are given in the subjoined table:—

	1900.	1901.		1900.	1901.
Rails	759,814	732,000	Blooms and billets	280,220	.....
Plates and angles	96,108	.....	Bars	221,795	.....
Sleepers	27,291	.....	Total	1,385,228	.....

Modern Improvements in the Manufacture of Pig Iron.

By John Birkinbine.

The rapidly increasing production of pig iron in late years is due to numerous changes in plant construction, equipment and management which have resulted from the application of scientific principles and efficient business acumen. Among these factors may be mentioned the following:—

1. The exploitation on a liberal scale of large iron ore deposits which have made available immense quantities of ore previously unexpected, the erection of docks, construction of vessels and special handling appliances for the transportation and delivery of these quantities. Similar developments of coal mines, construction of coke ovens and the introduction of means for cheaply handling

both the crude material and the finished product have supplemented the efforts to secure supplies of ores.

2. The growth of the steel industry, first in the line of "Bessemer" steel and later in the development of "open hearth" steel has had a most potent influence in furnishing a market for metal and in regulating its quality.

3. The enlarged proportions of blast furnaces, with greater blast pressure and higher blast temperatures have produced not only furnaces of greater size, but have increased very largely the capacity from a given unit. Possibly the extent to which technical investigation has been followed in the operation of the blast furnace and the determination of the characteristics of ore, fuel and flux, has done as much as anything else to achieve these results and surely it is not second to the wonderful perfection of mechanisms which have been introduced in the plants which are now prominent producers.

Iron Ores.—In late years three or four prominent iron ore mines in the United States have each produced 1,000,000 tons or more of ore, and the maximum output from a single operation, either in the United States or, as far as known, in any other part of the world, was reached by the Fayal mine, which in 1901 supplied 1,681,000 tons of merchantable ore. Since 1883 from 5 to 15 of the iron ore mines in this country have contributed over 500,000 tons each in a year. Most of the mines reporting these large outputs are in the Lake Superior region, where navigation is suspended for four or five months in the year, and although development work is prosecuted during the winter, it may be considered that these large quantities are won at the rate of from 2,500 to 7,000 tons per working day from the mines mentioned. There are important mines elsewhere, and among those which have supplied 500,000 or more tons per annum are individual mines in Alabama and Pennsylvania. These statements taken in connection with the fact that the bulk of this ore is sent to furnaces from 500 to over 1,000 miles distant and that shipments from the Fayal mine in one month reached 375,814 tons, demonstrate the growth of the iron ore mining industry.

It is, however, not only the facilities for mining large quantities of iron ore cheaply which command attention, but also the means of transporting them from mines to vessels and delivering them into vessels' holds, the equipment, capacity and speed of the vessels themselves and finally the appliances for removing the ore from these vessels and transporting it to furnaces.

The quantity of iron ore mined in the United States in the last decade has increased from 16,000,000 to 29,000,000 long tons by the improvements in mining machinery and mining methods in the use of large cars, heavy locomotives, substantial railroad construction, powerful vessels, and elaborate dock equipment, and by the liberal employment of steam, electricity and compressed air. An important feature also has been in the close application of chemical analyses to the grading of iron ores, whereby an ounce of phosphorus in a long ton of iron ore may place it within or without the Bessemer limit. The Lake Superior region produces about three-quarters of the iron ores won from the mines of the United States.

The Bessemer steel industry increased the demand for iron carrying small amounts of phosphorus, and threatened to interfere with the development of a

few large iron ore deposits in which this element was in greater proportion than was desired or was acceptable as within what is commercially known as the Bessemer limit (a limit which has been practically reduced until in a standard ore but one part of phosphorus to 1,300 or 1,400 parts of iron is allowed). However, with the later growth of the open-hearth steel industry, the demand for ores not within the Bessemer limit has been increased, although a low phosphorus ore is preferred in the majority of cases.

Fuel.—The original fuel used in the blast furnaces until 1840, was confined to charcoal, then anthracite and bituminous coals were employed, and in 1855 the quantity of pig iron smelted with anthracite exceeded the quantity made with charcoal, but as the application of coke in place of raw bituminous coal advanced, it passed anthracite in 1875 as a popular blast furnace fuel. At present fully 87% of the blast furnaces for iron in the United States are charged with coke; anthracite ranking next in order, and charcoal last. The output of the charcoal furnaces in 1901 amounted to only 382,441 tons.

Some of the pig iron reported as made with anthracite or charcoal is produced with a mixture of coke and the fuels named.

To supply the demands of the large furnaces, a liberal development of bituminous coal mines and an augmentation in the number of coke ovens has been necessary. The selection of desirable coking coals in which the proportion of sulphur and phosphorus are within the required limits has encouraged the introduction of by-product ovens in which the products of distillation are in part used for heating these ovens, obtaining a large yield from the coal charged and permitting the utilization of coals in which the volatile matter is insufficient to maintain the heat in the ordinary bee-hive oven. It is now proposed to improve still further the coke made in some of these by-product ovens by compressing the coal in advance, thus obtaining a greater yield from each charge and securing a denser product and compensating for the swelling or contraction which is often troublesome in the manipulation of the ovens.

A late departure in the supply of fuel has been by the erection of ovens at the blast furnace, the coal being brought from a distance. This departure is confined to by-product ovens, and it is expected to obtain value either from the by-products, or the use of the excess gas if the coal used is high in volatile matter.

Blast Furnaces.—The growth in the dimensions of blast-furnace stacks received a decided impetus within a few years and stacks were constructed higher and of larger bosh and crucible diameters than had heretofore been built except in isolated instances. It is questionable whether further increase in these directions will be generally considered as desirable. There are apparent limitations in the height of the furnace and in the diameter of the crucible which affect the fuel, especially when it is used in connection with a large proportion of finely comminuted iron ore.

The descending column in a large blast furnace subjects the coke (the fuel now generally used) to considerable abrasion, producing in a high furnace with a longer shaft more coke dust than in a low furnace. Furthermore, the method of handling the coke from the cars to the bins, thence to the weigh cars and the skips, and finally through two charging bells, encourages its decrepitation. It is

also claimed that in the long narrow shafts of the higher furnaces, the swelling of the reduced ore affects the blast resistance. The pressure to overcome this resistance as well as that due to the column of stock and that required to permeate the wider hearths, seems to exceed the resisting capacity of many of the cokes, and as a result the decrepitation of the coke is still further increased, and accumulations of this fine material form in the blast furnace above the point where the fuel may be expected to be in active combustion. Owing to obstructed blast, pressures which under normal conditions would not exceed 12 to 15 lb. per sq. in. at the tuyeres are increased to 20 lb. and over with a tendency, under existing conditions, for the furnaces to channel and work irregularly. At the time of writing few of the larger furnaces are producing proportionately more iron or iron on lower fuel consumption than those which a few years ago were considered large. That is, blast furnaces ranging from 20 ft. bosh diameter up to 23 ft., with crucibles 13 to 16 ft. diameter, and heights from 95 to 105 ft., are not as a rule doing better work or materially exceeding in output those of a bosh diameter not over 20 ft., with crucibles not exceeding 12 or 14 ft. in diameter and of a height approximating 90 ft.

A radical development has been made in the means of delivering the raw materials into the furnaces. The general method had been to drop the ore, flux and fuel from cars running on trestles to piles below the tracks, then to shovel or fork the material into charging barrows and to wheel them to a vertical elevator or inclined plane, and there consign them to top fillers, who deposited their contents on to the bell of the furnace. This is being replaced by a series of bins, which form portions of the trestle; chutes from these bins deliver the material into charging scale cars, which in turn shoot the ore, flux or fuel into skip cars, although at some furnaces, the materials are fed direct from the bins to the skip cars. The skip cars travel on inclined planes and are dumped at the top of the furnace into a receiving hopper with bell, which when full deposits its load in the main hopper, the upper bell closing as a seal. Friable material such as coke and such ore as breaks readily is more finely comminuted in the bin system, as described above, than in the older method mentioned, and it is probable that the modifications of the stock-handling appliances will be in the direction of reducing this decrepitation and loss. The use of bins has necessitated a more liberal crushing of ore than has previously prevailed, as it is difficult to discharge lumps of large size through the spouts. This necessity for crushing also produces ore of a more uniform size and undoubtedly facilitates the smelting process.

Good management recognized the disadvantage of dividing a charge which may represent as much as five tons of one kind of ore into as many as 10 barrows, to be pushed by men to the foot of the hoist or incline. By means of bins and of scale and stock cars these charges are now fed in larger units, which results in a material saving of labor and a full supply to the large furnaces. In discussing the handling of ores, fuel and flux are also included.

In constructing furnaces the whole equipment must be designed for the work, and a plant to make 300 tons per day should have its boiler capacity, its blowing engines, its hot-blast stoves, etc., all proportioned for this product. If a fur-

nace is to produce 500 tons per day, a corresponding increase is demanded in all other features of the plant. This increase is not confined to dimensions of the shell and of the parts mentioned, but extends to steam pipes, gas and blast connections, and to the apparatus for delivering the stock to and removing the product from the furnace. The maximum pressure under which the volume of blast is to be delivered controls the capacity and strength of the blowing engines and the power of the boiler equipment. Consequently the large furnaces require the expenditure of an amount of money greatly in excess of those of more moderate size.

Hot-blast stoves have increased in height and diameter and the simpler forms with liberal openings and substantial partitions have prevailed. Some stoves exceed 100 ft. in height and others are 25 ft. in diameter; the shell is made of heavy steel, and as a rule, four stoves are allotted to each blast furnace, with the object of obtaining a uniform temperature rather than of securing the maximum heat, which may be obtained intermittently from the incandescent refractory lining.

In manipulating the furnaces a steam or air gun for closing notches and the liberal application of large metal troughs with skimming attachments for delivering iron and cinder into ladles are features common to the more modern plants.

An item of blast-furnace construction which in late years has received attention is the multiplicity of tuyeres, but this branch, like many other innovations in blast-furnace equipment resulting from a change without careful study, has been disastrous in a number of instances. The single open tuyere of the older charcoal furnaces was supplemented by another opposite to the first, and as the furnaces were enlarged and the tuyeres closed, three, four, and sometimes five tuyeres were used. Later the number of tuyeres was increased but up to within the past decade few furnaces exceeded six, or at most, eight tuyeres. The introduction of as many as 20 tuyeres in the hearth of a large blast furnace encouraged managers to follow this example, and there are instances where sixteen tuyeres were placed in a relatively small crucible. The craze for a large number of tuyeres has however subsided, and in most of the large furnaces the number has been reduced to ten or twelve, and in some cases to eight tuyeres.

The liberal use of water cooling for the bosh walls and the crucibles has increased the number of bosh plates, and decreased the intervals between these plates so that in some blast furnaces the boshes are practically a series of bronze water-cooled boxes separated by light fire-brick walls, which are held in place by substantial bands.

In removing the gases from the larger furnaces, two down-comers or a bifurcated down-comer connecting on opposite sides of the furnace-top and uniting in a common conduit, lead to large dust catchers, and in several instances the dust catchers are connected with gas washers to collect and reserve for future use the accumulation of fine ore and coke which is carried from the furnace by the outgoing gases. This fine ore is principally the comminuted material which comes from some of the large mines in the Lake Superior region, and the amount

produced is influenced by the growing quantity of concentrated iron ore which is being utilized in the blast furnaces.

Considerable dust also results from the breaking of the coke as above mentioned. To reduce the amount of dust carried over by the flues some late constructions withdraw the gases in several vertical flues extending some distance above the top of the furnace and then connect to a common down flue.

Another specialty of modern blast-furnace construction is the application of water tube boilers in place of the long cylindrical boilers with mud drums and the return flue boilers formerly used at most of the blast furnace plants. The water tube boilers occupy less ground space and produce steam more rapidly, but they do not possess the reserve capacity, as a rule, of the older form. Taking into consideration the foundations, setting and buildings to cover the boilers, the cost of installing is in favor of the water tube type. This is especially true when the higher pressure available is considered. A modern furnace plant is now equipped with from 3,000 to 4,000 H.P. of boilers.

In blowing machinery, aluminum grid valves or positive motion air valves for the blowing cylinders, economical valve motions for steam cylinders, and the application of condensers, or compounding engines so that twin engines can be run as one compound machine, has been noticeable. These engines have been mostly of the vertical type with the blowing cylinder above the steam cylinder, but some large lately installed plants are of the horizontal type. As the requirements of the larger furnaces, both for volume and pressure, exceed those of former practice (the volume in some furnaces reaching 70,000 cu. ft. per minute and the pressure at times approximating 30 lb. per sq. in.), these engines are costly features and require commodious and high engine houses of sufficient rigidity to support traveling cranes so that in case of emergency the parts of the ponderous engine can be quickly handled.

With the increased number of tuyeres and the enlarged diameter of those used and the general application of water cooling appliances about the bosh of the furnace, and about the valves at hot blast stoves, added to the requirements for boilers and for condensing steam, the demand for water for a blast furnace of large size is great, and where casting machines are used an additional quantity is required. At present in the larger plants from 3,000,000 to 4,500,000 gal. per day per furnace is provided.

In handling molten metal and cinder, the prevailing practice is to dispense with the familiar cast house in which iron was cast into pigs, and to discharge the molten metal and the cinder into ladle cars, the former being transported either to mixers at Bessemer plants or to casting sheds where the pig iron is run into ordinary molds or to casting machines in which moving molds on strands of chains or rotating about a central pivot are filled and automatically emptied. Comparatively little of the raw materials received or of the metal produced at a modern blast furnace is handled by manual labor, the force about the furnace being confined practically to those who direct the discharge of the raw materials from the railroad cars into the bins and from the bins into the scale cars, etc., or to those who control the flow of metal or cinder from the tapping holes to the ladle cars. There is necessarily a considerable amount of labor required

about a blast furnace to attend to the engines and boilers, tuyeres, hot-blast stoves, etc., and in the stock yard also there are men to receive stock and clean up, while others are necessary to look after the minor details of furnace operation, but the tendency in late years has been to eliminate manual labor in the operation of the blast furnace.

The casting machine has made a radical change in the form of pig used, a slab rather than a bar representing the shape that is cast on most machines. These machines have also done away with the sand allowance (as did also the stationary chills used in cast houses) and has practically abolished the pig iron ton of 2,268 pounds. The future improvements in casting machines seem to be in reducing the number of wearing parts and possibly of producing pigs in the form of a small ingot.

The equipment of ladles to handle the liquid metal and cinder as it runs from the furnace, to convey the former to the mixer, converter or casting machine, and the latter to dump piles, together with the locomotives to handle the ladles and the extensive track systems necessary to have ample ladle capacity always available at the furnace or to accommodate cars loaded with ore, fuel, flux, flue-dust, etc., all help to swell the total outlay for a single plant until those lately constructed have cost from $750,000 to $1,000,000 each. This fact, coupled with the desirability of having several blast furnaces in one plant connected as a means of supply for a steel works, and the necessity of having control of ore and fuel supplies for an industry which makes such heavy demands, has taken the blast furnace largely out of individual or partnership control. The majority of those lately constructed belong to companies which, in a number of instances, have consolidated to form aggregations of capital operating a number of blast furnaces that demand enormous supplies of raw materials; hence plants of this type have become important features in the business enterprise of the country.

While this paper is not intended to be statistical, the following figures, indicating the active furnaces and their product, will emphasize the development of the pig iron industry in the United States during the past 25 years:—

Year.	Furnaces in Blast at Close of Year.	Total Number of Furnaces.	Production. Gross Tons.
1875.....	298	713	2,023,733
1880.....	446	701	3,835,191
1885.....	276	591	4,044,526
1890.....	311	582	9,202,703
1895.....	242	468	9,446,308
1900.....	232	406	13,789,242
1901.....	266	406	15,878,584

Assuming that the mean of the total number of furnaces in blast at the commencement and close of each year above quoted was a fair average of those operated throughout the year and that these were producing 300 days per annum, the approximate average tonnage of pig iron per furnace per day is: for 1875, 21 tons; for 1880, 31 tons; for 1885, 53 tons; for 1890, 94 tons; for 1895, 147 tons; for 1900, 176 tons; and for 1901, 213 tons.

Of the total pig iron production for 1901, 9,596,793 gross tons consisted of Bessemer iron and 1,448,850 of basic pig iron.

The blast-furnace manager must keep each of his large furnaces supplied with

1,500 to 2,000 tons of raw material per day, and must arrange a mixture of the ores available in order to secure a metal of the desired quality; the composition of the ores, the fuel and the flux must be carefully analyzed and watched to produce at each cast more than 100 tons of metal in which the phosphorus, sulphur, carbon and silicon is within very narrow limits.

A liberal supply of water and of gas for boilers and also of gas for hot-blast stoves must be maintained. The operation of the blowing and the pumping machinery as well as that of the electric plant for lighting and power is also under constant surveillance; no break should occur day or night, week-day or Sunday.

Under the conditions of modern blast furnace operation it is not remarkable that the changes in the personnel of management are numerous, for the physical and mental strain is severe and continuous. A manager is judged by his results, he shares in the responsibility of imperfect design and suffers from the delivery of undesirable material, which increases his anxiety and trouble. When the chemical and physical limitations under which the modern blast furnace is operated are taken into account, in connection with the large product demanded, a product whose deficiencies are only recognized in subsequent operations in the converter or mill, it is evident that the position of a blast-furnace manager is not a sinecure.

Independent of the increased size of the blast furnace, there has been an increase in output per furnace, and although the production of the United States in 1901 has never been exceeded, it was obtained from fewer furnaces than were in operation two decades ago when but 1,706,793 gross tons were produced. This result has been brought about by the perfection of the blowing machinery, the use of well constructed hot-blast stoves with the connections (gas or steam) kept airtight and of such proportions as to stand the severe strain placed upon them; but primarily to a more thorough knowledge of the reactions which take place in the blast furnace.

As a result, the large output has been accomplished in many instances by marvelously low fuel consumption. Records have been made which show that in producing hundreds of thousands of tons of pig iron per annum, a consumption of less than 1,800 lb. of coke per ton of metal has resulted. While this economy in operation has been pronounced, the life of the blast furnace campaigns has been extended by the use of water-cooling appliances and improved details of construction. At least three of the blast furnaces in the United States have made continuous campaigns wherein over 1,000,000 tons of pig iron were obtained from each furnace, the campaigns lasting approximately eight years.

Such results would seem to suggest that the criticism upon American blast-furnace practice, based upon the rapidity with which the furnaces are driven being prejudicial to the life of the plant, has not been verified, for large products have been obtained continuously and low fuel consumption secured. It is not an unusual circumstance to find blast furnaces averaging about 500 tons of pig iron daily and in individual instances as much as 800 tons per day has been credited to a furnace as a "spurt." Such a "spurt" represents as the daily output of a single furnace a quantity of metal as great as one of the cold blast charcoal furnaces, which was the prevailing type prior to 1850, would have produced in a whole year.

LEAD.

THE aggregate production of all varieties of lead in the United States during 1901 showed an increase over the production in 1900 exceeding by 3,015 tons the record figures of 1900. The grand total of soft, desilverized and antimonial leads produced from both domestic and imported ores and refined from imported base bullion in 1901 amounted to 392,344 short tons, as compared with 379,248 short tons in 1900. The totals of desilverized, soft and antimonial leads in short tons, derived from domestic ores in 1901 and 1900 were respectively as follows: Desilverized, 211,368, 221,278; soft, 57,898, 47,932; antimonial leads, 10,656 (includes production from foreign sources), 9,906 (includes 3,200 tons from foreign sources), total domestic leads, 279,922, 279,107.

PRODUCTION AND CONSUMPTION OF LEAD IN THE UNITED STATES. (IN SHORT TONS.)

Year.	Stock of Refined, Jan. 1. (a)	Produced from United States Ores.				Imported in Ores and Bullion.	Total Supply.	Consumed.	Exported in all Forms.	Stock of Refined, Dec. 31. (a)
		Desilverized.	Soft.	Antimonial. (b)	Totals.					
1897....	13,024	144,649	45,710	7,359	197,718	92,117	302,859	211,345	60,353	31,161
1898....	31,161	169,364	50,468	8,643	228,475	89,209	348,845	246,989	78,168	23,688
1899....	23,688	171,495	40,508	7,377	217,085	76,423	317,196	215,662	74,944	26,590
1900....	32,320	221,278	47,923	9,906	279,107	108,341	414,768	241,440	100,288	66,640
1901....	66,640	211,368	57,898	10,656	279,922	112,422	457,984	307,151	97,100	53,733

(a) Includes lead in bond, which amounted to 16,618 tons at the end of 1901, 21,190 tons at the end of 1900, 11,320 tons at the end of 1899, 7,345 tons at the end of 1898, and 6,694 tons at the end of 1897. (b) The entire production of antimonial lead is entered as of domestic production, although part of it is of foreign origin; it is, however, impossible to separate this in the statistics; owing to this inability the division of the American production between antimonial and desilverized is not quite accurate, though the error is not important.

The decrease of 10,025 short tons in the production of desilverized lead during 1901 was the first retrograde movement in the progress of the branch of the metal industry since 1895 and may be attributed to the overproduction in 1900, a year in which the stock carried over was very large, compared with the stocks in previous years. The decrease in the production of desilverized lead, however, was practically offset by the increase in the production of soft lead, which was 9,975 short tons and, including the increase in the production of antimonial or hard lead (a minor proportion of which is of foreign origin) gives a total production of desilverized lead and soft lead from domestic sources and

antimonial lead mainly from domestic sources amounting to 279,922 short tons in 1901, as compared with 279,107 short tons for the same products in 1900. Aggregates which are practically identical.

Colorado.—The production of lead in Colorado during 1901 was 74,056 short tons, valued at $6,419,131, against 82,137 short tons, valued at $7,770,196 in 1900. The production by principal counties for the two years, as reported by the Hon. Harry A. Lee, is given in the subjoined table:—

County.	1900.		1901.		County.	1900.		1901.	
	Short Tons.	Value.	Short Tons.	Value.		Short Tons.	Value.	Short Tons.	Value.
Clear Creek	2,497	$236,229	1,945	$168,601	Pitkin	13,726	$1,289,492	16,375	$1,419,364
Hinsdale	4,669	443,535	3,795	328,893	San Juan	8,789	831,495	7,736	670,607
Lake	31,300	2,960,964	26,180	2,442,629	Others	8,921	843,914	6,813	600,515
Mineral	7,476	707,227	5,260	455,992					
Ouray	4,789	448,340	3,952	342,590	Total	82,137	$7,770,196	74,056	$6,419,131

The quantity of ore mined in the Leadville district during 1901 amounted to about 850,000 long tons, valued at approximately $10,000,000, of which 35,000 tons were zinc ores, 70,000 tons manganese-iron ores, and the remainder lead and copper smelting ores. The quantity of sulphide ores produced could easily be increased to 1,000 tons per day could the smelters handle it. The sulphide bodies on the silver-lead belt have been opened principally through the A. M. W. Small Hope and Greenback combinations, while on the gold belt the Resurrection and New Monarch are the principal miners. The Diamond, Sedalia, Forest City and Fortune are also sinking to open the same shoot.

The zinc situation is very bright, it having been clearly proved that zinciferous ores can be profitably handled and the new smelter at Pueblo will give a market for 600 tons a day. The extension of the railroads to all important mines; the diminishing of the water in the downtown mines; the extension of the mineralized area; the forming of combinations to develop territory now lying idle; and the increased investment of Eastern capital, all contribute to the promising outlook for 1902.

With regard to the lead smelting situation, early in 1901 smelting charges were reduced on tailings and all ores containing a low percentage in arsenic and zinc, in Gilpin County, Colo. The cut in prices was initiated by the Kansas City Works, and effected a reduction from $3·50 to $2 per ton on tailings and ores on a 10% silica basis. In July, 1901, the smelting plants in operation in the Leadville district, Lake County, Colo., were the Arkansas Valley plant, handling 1,000 tons per day, and the Boston Copper Smelting Co. The remainder of the local output was smelted in Pueblo and Denver. Later in the year arrangements were being made for an increase in the roasting capacity of the Arkansas Valley plant to enable it to handle 3,000 tons more per month of the low-grade sulphide ores. At Salida, 60 miles from Leadville, the erection of the Ohio & Colorado Smelting Co.'s independent plant was begun. The plant will have a capacity of 1,200 tons of ore per day, of which 300 tons will be supplied by the New Monarch Gold Mining Co., owned by the same interests, and the balance will be secured by purchase from other Leadville mines.

Idaho.—The production of lead in the Cœur d'Alêne district in 1901 was 68,953 short tons, as compared with 81,535 tons in 1900. The output of silver in 1901 was 3,349,533 oz., as compared with 4,755,877 oz. in 1900. The statistics of silver and lead production in this State are based on direct returns from the mines, with an allowance of 6% for loss of lead in smelting and 2% for loss of silver. There are five important producers in the Cœur d'Alêne district who mechanically concentrate the low-grade ore to a product averaging about 50% Pb and 30 oz. silver per ton. The chief producers during 1901 were: The Bunker Hill & Sullivan Mining & Concentrating Co., Cœur d'Alêne Development Co., Larson & Greenough, Empire State-Idaho Mining & Developing Co., Frisco Consolidated Mining Co., Ltd., The Mammoth Mining Co., and the Standard & Hecla Mining Co. Considerable interest has been manifested in the Thunder Mountain district, which occupies about 600 square miles in the southeastern section of Idaho. The inaccessibility of the region, which can only be reached by trail, precludes the rapid development of the district even though the mines justify it. A 10-stamp mill began operations at the Dewey mine early in 1902 with promising results; the ores are low-grade breccia, with occasional streaks carrying high values but no well defined lodes, hence it is probable that considerable litigation over apex rights will result. The main body of the gold-bearing material is a rhyolite porphyry, breccia and tuff with fine gold disseminated throughout the mass; the thickness of the bed is estimated to vary from 60 to 600 ft. Specimen ore occurs as dendritic incrustations, which is apparently the result of secondary enrichment from circulating mineral solutions. A small smelting plant is being constructed by the Boston & Seven Devils Co., at Weiser, to treat the ores from the Peacock, Helena and Decorah mines, but will not be in full operation until the completion of the branch line of the Oregon Railroad & Navigation Co., from Weiser to the mines. The White Knob Copper Co. is erecting a smelting plant at Mackay, Custer County, which comprises two 300-ton blast furnaces. A 12-mile electric railway connects the smelter with the mines. The ores, so far as the mine development has been extended, consist of carbonates and oxides and are stated to contain an average of 4% Cu and $3 gold and silver per ton.

Iowa.—(By S. W. Beyer.)—The falling off in the demand for zinc has not materially affected the demand for lead, and most of the energy and capital formerly occupied in the development of zinc properties is now devoted to the opening of lead properties. Prospecting has been vigorously prosecuted during the past year, and several rich mineral bodies have been discovered. The demand ruled firm and the price steady throughout the year and those employed in the production of lead ore were able to secure good returns for their labor and capital. Practically all the ore produced was galena, and all of it was sold to the local smelter, owned and operated by William G. Watters, of Dubuque. The ore smelted during the year amounted to 1,500,000 lb., purchased at an average price of $23 per 1,000 lb. and cleaning up an average of 72% lead. The production of lead in Iowa during 1901 amounted to 600,000 lb., valued at $13,800. The lead smelted by William G. Watters was contributed by the following States: Iowa, 600,000 lb. ($13,800); Illinois, 700,000 lb. ($16,100); and Wisconsin, 200,000 lb. ($4,600). Total, 1,500,000 lb., $24,500.

Missouri.—The mining district of southeastern Missouri embracing St. Francois, Madison and Washington counties, experienced a prosperous year, and the output showed a substantial gain over previous records. Some valuable discoveries of new ore bodies within the limits of the productive area were made, and in one instance ore was found in outlying territory near Irondale. There was a large amount of improvement work done in extending the mining and milling facilities of the companies operating in the district, which placed them in position to increase their output during the coming year. The Federal Lead Co., now consolidated with the Guggenheim Exploration Co., erected a mill of 500 tons' daily capacity and began the construction of a large smelter at Alton, Ill., where the smelting operations of the company will be carried out in the future. The St. Joe Co. increased the capacity of its mill by 40 per cent., and opened two new shafts, while the subsidiary Doe Run Co. also extended its operations. The National, Desloge and Central mines made important additions to their plants. It is probable that the new deposit found at Irondale will begin producing during the present year; the Irondale Lead Co. has completed one shaft on the property, and the mill and smelter will be ready for operations before the middle of 1902. The Catherine Lead Co. became a producer for the first time last year. In the Joplin district the output of lead ore in 1901 was about 35,000 short tons. The average monthly prices per 1,000 lb. ore were as follows: January, $23; February, $22·50; March, $23·12; April, $23; May, $22·87; June, $23·25; July, $23·62; August, $23·50; September, $23·512; October, $23·06; November, $23·25; December, $23·25. The galena concentrate from the ores of southeastern Missouri frequently contains copper, which is not removed by the process of refining ordinarily practiced in the local smelting works, and causes some of the lead to become "chemically hard." At one works the crude lead contains about 0·2% Cu, which is subsequently reduced by refining to 0·02% Cu, the eliminated copper being gradually accumulated in a matte. An analysis of one carload of ore showed PbO 62·1%, Cu 0·61%, Fe 3·33%, CaO 5·85%, MgO 3·08%, SiO_2 1·39% and Ag 1·3 oz. per ton. The iron and copper exist in the ore as pyrite and chalcopyrite, and the lime, magnesia and silica represent the gangue of the ore.

Montana.—In March, 1901, the lead smelting plant of the American Smelting & Refining Co., at Smelter, near Great Falls, was shut down for an indefinite period. In April, operations at the company's plant at East Helena were suspended on account of labor troubles, but in June the work was resumed and continued throughout the year. The plant has been increased by the addition of a new furnace which, with the four already constructed, enables the company to smelt 850 tons of charge or 625 tons of ore per day. Three large bag houses have been built for the collection of flue-dust, also a large horizontal steel flue extending three-fourths of the way around the plant to conduct the fumes from the furnaces to the bag houses.

Texas.—The smelting plant of the American Smelting & Refining Co. at El Paso was almost completely destroyed by fire in July, 1901. An enlarged modern plant has been constructed on the ruins of the old one, and new furnaces were blown in April 15, 1902. The plant is now comprised of seven 200-ton lead

furnaces and three 250-ton copper furnaces, each set having its independent flue system and stack. The furnaces are charged mechanically by 6-ton cars operated by means of a street railroad motor and controller with third-rail system. The cars collect the charge at the ore beds, limerock and coke storage, and are run on to 15-ton hydraulic elevators. They are then elevated 38 ft. to the top of the furnaces, traveling over them to the charging doors, through which the loads are dumped directly into the furnaces. By this system two men handle about 1,000 tons per day. A similar system is used for charging the copper furnaces. The power plant is in duplicate, and consists of seven boilers, of a total of 1,250 H.P. and four blowers of a capacity of 30,000 cu. ft. of air per minute; the latter are direct connected to three tandem compound condensing Corliss engines. No belts are used in this plant except for driving a small blower of 10,000 cu. ft. capacity, which acts as a regulator. The central electric plant in the power house consists of two direct-connected, direct-current generators, mounted on the shafts of two cross-compound condensing Nordberg Corliss engines. The current from these generators is transmitted throughout the plant, operating sampling works, briquetting machinery, pumps, hoists, motor, cars, etc., displacing all of the small steam engines and steam pumps used in the old plant. The power plant is provided with two systems for condensing, one being a large Wheeler surface condenser, the other a Worthington central-elevated jet condenser, the idea being to use the surface condenser during a short period of the year when the water is so bad that it cannot be used in the boilers. During the balance of the year the jet condenser is in service and the surface condenser can be cleaned. The condensed steam from the surface condenser, with the necessary additional water goes back directly to the boilers when the surface condenser is in use. The power house is absolutely fireproof throughout, being of steel and brick with iron and cement floors and is provided with a traveling crane. The main conductors from the generators pass out through a tunnel into a brick and steel lightning arrester house, from which point the various distributing lines go to different parts of the plant. An interesting feature of the new work is the substitution of crude oil from Beaumont as fuel for the generation of power and for the roasting of ores in place of wood, coal or coke.

Utah.—The importance of Salt Lake City as a smelting center has been increased greatly, and by the end of 1902 there will be four comparatively new works in operation. These are the 500-ton Highland Boy smelter, the 400-ton Bingham plant, the new 1,000-ton (estimated) plant of the American Smelting & Refining Co., and the 850-ton plant of the United States Mining Co. The two latter will probably be in operation late in the year. Of the older plants which were taken over by the American Smelting & Refining Co., the Germania is the only one which continues in operation; the Mingo is dismantled and the Hanauer completely demolished. The new plant of the American Smelting & Refining Co., at Murray, Utah, is under construction and will doubtless be in operation before the end of 1902. The new works are situated close to the old Germania plant, and, while thoroughly modern, there has been no radical de-

parture in methods, the novelties being in details rather than in the general scheme.

The roasting department comprises a crushing mill and 2 furnace houses, one equipped with Brueckner furnaces and the other with hand-raked reverberatories. The ore is trammed over the roasting furnaces and charged through hoppers. The fire-boxes are arranged with step-grates and closed ash-pits, being fed through hoppers at the end of the furnace. The roasted ore is dropped into cars, which run on a sunken tramway passing under the furnaces and is carried to an incline up which the cars are drawn and afterward dumped into brick bins. From the latter it is spouted into standard gauge railway cars and taken to the smelting department. The roasted ore from the Brueckner furnaces is handled in a similar manner.

The blast furnace department comprises 8 furnaces, each 48×160 in. at the tuyeres, having 10 tuyeres per side, a tuyere passing through the middle of each cast-iron jacket 16 in. wide, and 6 ft. long, which is rather extraordinary. The furnaces are arranged for mechanical charging. The furnace house is constructed entirely of steel and the matte is tapped from the settling boxes and runs into pots on the ground level. The slag overflowing into single-bowl, Nesmith pots, handled by small locomotives. The foul slag is returned by a continuous pan-conveyor to a brick-lined cylindrical steel tank behind the furnace house, whence it is drawn off through chutes as required for recharging.

The charges are made up on the ground level, immediately behind the furnace house. The ore and fluxes are brought in on trestles, whence the ore is unloaded into the beds and the fluxes into elevated bins. These are all in the open, there being only two small sheds where the charges are made up and dumped into the cars which go to the furnaces. There are two inclines to the latter. At the top of the inclines the cars are landed on a transferring carriage by which they can be moved to any furnace of the series.

The dust flue extending behind the furnace house is arranged to discharge into cars on a tramway in a cut below the ground level. This flue, which is of brick, connects with the main flues leading to the chimney. The main flues are built of concrete, laid on a steel frame in the usual manner and are very large. For a certain distance they are installed in triplicate; then they make a turn approximately at right angles and two flues continue to the chimney. At the proper points there are huge dampers of steel plate, pivoted vertically, for the purpose of cutting out such section of flue as it may be desired to clean. Each flue has openings, ordinarily closed by steel doors, which give access to the interior. The flues are simple tunnels, without drift-walls or any other interruption than the arched passages which extend transversely through them at certain places. The chimney is of brick, circular in section, 20 ft. in diameter and 225 ft. high.

The boiler house is equipped with 8 internally fired corrugated fire-box boilers, arranged in two rows, face to face. Between the rows is an overhead coal bin, from which the coal is drawn directly to the hoppers of the American stokers, with which the boilers are provided. Adjoining the boiler house is the engine house, containing two cross-compound, horizontal Allis-Chalmers (Dickson) blowing engines for the blast furnaces, and two direct-connected electrical generating

sets for the development of the power required in various parts of the works. A traveling crane, built by the Whiting Foundry Equipment Co., spans the engine house.

A noteworthy feature of the new plant is the concrete paving, laid on a bed of broken slag, which is used liberally about the ore yard and in other places where tramming is to be done, including the floors of the roasting furnace houses. The whole plant is well laid out with service tramways and standard gauge spur tracks and the design has been obviously to save manual labor as much as possible.

Philippine Islands.—G. F. Becker has reported the partial development of a lead mine near the town of Cebú, on Cebú Island, and a deposit of ore at Torrijos, Marnidugue Island, showed a value of 96 g. silver, 6 g. gold, and 565·5 kg. lead per metric ton.

Production of Lead in Foreign Countries.

Algeria.—The Aïn Kechera lead and silver mines are being developed, and the concessions asked for by the owners will probably be granted by the Government, as the official engineer has reported favorably. The ore from the mines will be shipped from Callo.

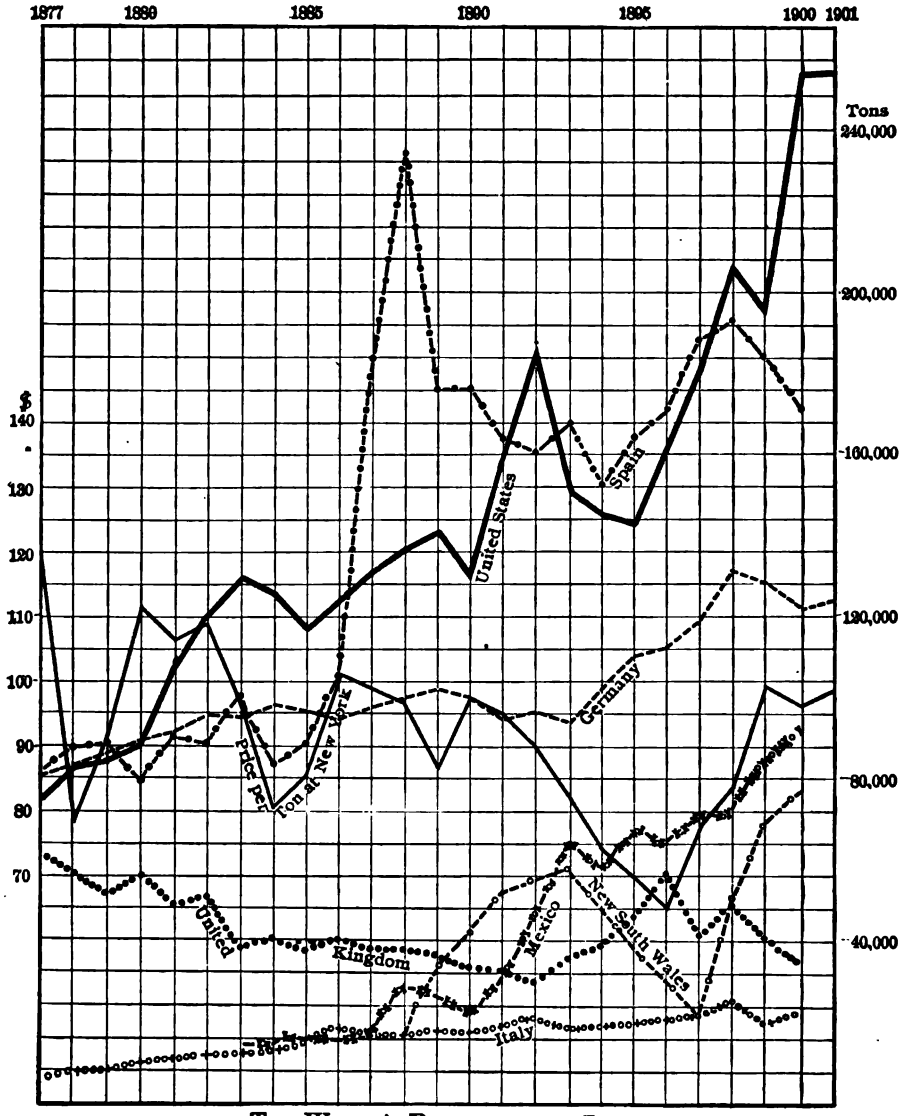
Australia.—The Broken Hill Proprietary Co., during the six months ending May 31, 1901, treated 133,862 tons of ore and concentrates for a yield of 26,361 tons lead, 302 tons antimonial lead, 3,240,756 oz. silver, and 1,342 oz. gold. The average results per ton were 19·69% lead, 24·21 oz. silver, and 0·01 oz. gold. As regards output, the operations were very successful, but there was a shrinkage in profit owing to the lower prices ruling in the market for lead and to the increased costs of smelting. Work was begun in January to connect the smelting works with certain iron ore leases in South Australia from which the company intends to derive its supply of flux; the cost of the iron ore consumed in the furnaces has heretofore been an important item in the treatment charges. Extensive development work was carried out in the mine, particularly in lowering the main shafts and opening levels, which added materially to the ore reserves. Experiments with magnetic concentrators were continued; one machine was installed which gave good results, but it is not intended to erect a plant until exhaustive trials have been made. The coke ovens at Bellambi were put in operation and the first trials were very satisfactory. During the semester ending November 30, 1901, the gross profit was £669,316, and the net profit, after deducting general expenses and depreciation, was £43,319. The dividends paid were £48,000, showing a deficit of £4,681. The surplus brought forward was £548,076; leaving a balance of £543,395 to the current half-year.

The total extraction of ore for the half-year was: From open-cut, 63,533 tons; from underground, 242,095; total, 305,628 tons.

The chloridizing and leaching plants were kept running for 4·5 months only, when they were closed down, as the ore immediately available from the open-cuts was not of a suitable nature for this process. The two concentrating plants continued to do good work. The slimes from the mill, which are difficult to deal with at the smelting works, are now being sintered at Broken Hill.

Smelting operations at Port Pirie continued without interruption. The ton-

age of ore, concentrates, etc., smelted amounted to 105,255 tons, with an average yield of: Lead, 18·6%; silver, 17·92 oz. per ton. The refinery treated 18,984



THE WORLD'S PRODUCTION OF LEAD
IN METRIC TONS

tons of silver-lead bullion, producing: Silver (fine), 2,296,755 oz.; gold, 7,531 oz.; soft lead, 18,225 tons; antimonial lead, 258 tons.

In addition to the ore smelted at Port Pirie, a quantity of concentrates was sold

LEAD PRODUCTION OF THE WORLD. (*a*) (IN METRIC TONS.)

Year.	Austria.	Belgium.	Canada.	Chile.	France.	Germany.	Greece.	Hungary.	Italy.
1896	9,769	17,223	10,977	594	8,232	113,793	15,180	1,911	20,786
1897	9,680	17,023	17,698	370	9,916	118,881	16,486	2,527	22,407
1898	10,340	19,330	14,477	13	10,920	132,742	19,193	2,305	24,543
1899	9,736	15,700	9,917	171	15,981	129,225	19,059	2,166	20,543
1900	10,650	16,365	33,190	14	15,210	121,513	16,395	2,031	23,763

Year.	Japan.	Mexico.	New South Wales. (*c*)	Russia.	Spain.	Sweden.	United Kingdom. (*b*)		United States.	Totals.
							Foreign Ores.	Domestic Ores.		
1896	1,958	63,000	30,000	262	167,016	1,530	25,869	31,311	158,479	676,662
1897	1,737	71,637	22,000	450	189,216	1,480	13,312	26,988	179,369	731,167
1898	1,705	71,442	50,000	241	196,392	1,539	23,239	25,761	207,271	781,615
1899	1,999	84,656	70,000	342	184,007	1,606	17,571	23,929	196,938	803,273
1900	1,877	84,700	78,500	350	176,600	1,424	35,000		253,204	870,846

(*a*) The statistics for Austria, Belgium, Canada, France, Germany, Hungary, Italy, Japan, Russia, Spain and Sweden are from the official reports of the respective governments except where otherwise noted. Those for Greece are based on the authorities given under the general table of mineral production of Greece in a subsequent part of this volume. Those for the United States are from data collected by THE MINERAL INDUSTRY. Those for the United Kingdom as specified in note *b*.

(*b*) The production of lead in the United Kingdom is given in two columns. One gives the amount of lead derived from domestic ores, the yield of which is calculated at 95%, as reported in the official British blue books. The other column gives the production of lead in the United Kingdom from foreign ores smelted there. These figures, which are not reported in the official blue books, are obtained by deducting the production of British lead from the total output of the lead smelters of the United Kingdom as stated in the *Statistische Zusammenstellungen über Blei, Kupfer, Zink und Zinn* of the Metallurgischegesellschaft, Frankfort-on-the-Main.

(*c*) From the *Statistische Zusammenstellungen* of the Metallurgischegesellschaft, Frankfort-on-the-Main. These figures comprise only the lead exported to Europe and America. The actual production of lead in New South Wales is much larger than shown here, especially in late years, during which there have been large exports to China, but it is impossible to obtain statistics as to what it really amounts to. (*d*) Estimated.

PRODUCTION, IMPORTS, EXPORTS AND CONSUMPTION OF LEAD IN THE CHIEF COUNTRIES OF THE WORLD. (IN METRIC TONS.)

		Aust'a Hungary. (*a*)	Belgium. (*b*)	France. (*c*)	Germany. (*d*)	Italy. (*e*)	Russia. (*f*)	Spain. (*g*)	Switzerland (*h*)	United Kingdom. (*i*)	United States. (*j*)
1899	Production	11,902	(*k*)	15,981	129,225	20,543	322	184,007	*Nil.*	41,500	196,938
	Imports	9,071	60,649	67,149	55,635	3,990	36,303	*Nil.*	4,388	201,551	86,016
	Totals	20,973	.....	83,130	184,860	24,533	36,625	184,007	4,388	243,051	282,954
	Exports	258	41,618	3,909	24,491	2,497	*Nil.*	169,007	204	24,083	67,846
	Consumption	20,715	.....	79,221	160,369	22,036	36,625	15,000	4,184	218,968	215,108
1900	Production	12,681	16,365	15,210	121,513	23,763	230	176,600	*Nil.*	35,500	253,204
	Imports	8,091	58,141	58,535	70,252	3,257	20,000	*Nil.*	.....	198,506	93,660
	Totals	20,772	74,506	73,745	191,765	27,020	20,230	176,600	.....	234,006	346,864
	Exports	393	46,566	4,749	18,825	5,018	*Nil.*	153,939	.....	13,393	90,980
	Consumption	20,379	27,940	68,996	172,940	22,002	20,230	22,661	.....	220,613	255,884

(*a*) From *Statistisches Jahrbuch des K. K. Ackerbau Ministerium* and *Magyar Statisztikai Evkönyv.*

(*b*) Production from *Statistiques des Mines, Minières, Carrières, et Usines Métallurgiques.* Imports and exports from *Annuaire Statistique de la Belgique.*

(*c*) From *Statistique de l'Industrie Minérale.*

(*d*) Production, imports, and exports from *Statistisches Jahrbuch für das Deutsche Reich.*

(*e*) From *Rivista del Servizio Minerario.*

(*f*) From *Sbornik Statisticheskikh Svedenie o Gornozavodskoi Promyshlennostie Rossie v zavodskom Godu*, St. Petersburg.

(*g*) From the *Reports of the Comision Ejecutiva de Estadistica Minera.* Imports and exports from the *Revista Minera de Espana.*

(*h*) From *British Statistical Abstracts* and from figures furnished by the *Direction Générale des Douanes Fédérales*, Berne. Statistics not available for 1900.

(*i*) Production from statistics of the Metallurgischegesellschaft, Frankfort-on-the-Main. Imports and exports from Board of Trade returns.

(*j*) The statistics of production are those collected by THE MINERAL INDUSTRY; those of imports and exports are from the reports of the Bureau of Statistics, Washington.

(*k*) Not stated.

for export, bringing the output of finished products up to 29,944 tons lead and 2,835,954 oz. silver.

The Broken Hill Proprietary Block 10 Co. in the six months ending September 30,1901, treated 81,852 tons crude ore, producing 13,676 tons concentrates, with a total content of 464,826 oz. silver and 8,816 tons lead. The net profit on the half-year's operations compared with the preceding semester showed a marked decline.

The declared net values of the exports during 1901 was as follows: Silver, silver-lead, and ores, £1,854,463; lead (pig, etc.), £100,501; zinc (concentrates), £4,057. The bulk of the output was contributed by the Broken Hill mines, and the fall in the prices of silver and lead during 1901 practically crippled the industry and caused the closing down of all but three of the principal mines.

The Smelting Co., of Australia, with the plant at Dapto was reorganized early in 1902, and, while the properties have not yet been transferred, negotiations are in progress for ore supplies and for a reduction of railway rates.

Canada.—The production of lead in Canada during 1901 was 25,378 short tons, as compared with 31,679 short tons in 1900. The decrease of output is attributable to low prices for the ores during the year and to difficulties encountered in marketing the ores profitably with the smelters in the United States.

British Columbia.—(By W. M. Brewer.)—The silver-lead ores of British Columbia are confined apparently to the southeastern portion of the Province in the Slocan, Trout Lake, Windermere, Kaslo, Lardeau and Fort Steele mining divisions. Besides these occurrences there have been reported discoveries of silver-lead ores near Cowicahn Lake and the Gordon river on Vancouver Island. The progress in mining in the silver-lead districts has not been satisfactory for the past two or three years, owing to labor troubles and the decline of the market in the United States for British Columbia ores. But since the Dominion Government has offered a bonus for refined lead, and the Canadian Smelting Co. at Trail has taken the matter up seriously and commenced the installment of a plant, it is expected that the industry will progress much more satisfactorily in the future than in the past. The Trout Lake and Slocan ores, as well as some of those in the Windermere district, generally carry quite high silver values in addition to the lead. Among the most important of the silver-lead mines are the St. Eugene and North Star mines in the Fort Steele mining division; these are considered among the most extensive bodies of concentrating ores on the North American continent. The dividends paid by the Payne Reco, Slocan Star, Last Chance, Ruth, North Star, Bo'sun, Goodenough, Rambler, Cariboo and other silver-lead mines in British Columbia demonstrate that this class of mining has been profitable and satisfactory. The report of the reorganized Hall Mining & Smelting Co., British Columbia, for the fiscal year ending June 30, 1901, shows a capitalization of £325,000 in £1 shares, of which £275,000 had been paid in; also £24,560 6% debentures. The net profit for mining and smelting amounted to but £1,011. The two furnaces treated 21,657 short tons of purchased lead ores during the year.

Chile.—(By W. T. Mathewson.)—The Playa Blanca plant, owned by M. Guggenheim's Sons, of New York, was in operation during the greater part of the year. The smelting works consist of a blast furnace and cupellation department

of nine small furnaces. The ore was derived from the Pulacayo mine of the Huanchaca Co., of Bolivia, the base bullion being shipped to Perth Amboy, N. J. During the first months of its operation the plant was worked at a profit, but later owing to a decrease in the lead contents of the ore other sources of ore supply had to be sought. Lead slags were imported from Oruro, Bolivia, and concentrates from Australia and British Columbia. The importation of such ores, however, was found too expensive, and during a part of 1901 the silver ore was matted with the local copper ores, which contain about one-third of the copper in the form of atacamite. These ores prove undesirable for smelting on account of the volatile copper compounds which carried off large quantities of silver, as well as copper, in furnace gases. For this reason the company decided to close down the plant, which was done in December, 1901. Since that time the ore has been shipped to the company's works in the United States. The output of the Playa Blanca smelting works during its operation by M. Guggenheim's Sons was 7,800 tons of copper matte assaying 50% copper and 390 oz. silver per ton.

Germany.—The production of pig lead in Germany during 1901 amounted to 123,098 metric tons, as compared with 121,513 metric tons in 1900; the production of litharge during 1901 was 4,101 metric tons, an increase of 1,013 over the production of 3,088 metric tons in 1900.

Greece.—The lead mines of Greece were actively operated in the early part of 1901, but later, due to the decline in the price of lead, many of the mines were forced to shut down. None of the Laurium companies has realized good profits, and the Laurium Lead Works Co. declared no dividend for the closing six months of the year. The smelters treated 340,000 tons of mixed ores and produced 17,694 tons of pig lead which averaged 75 oz. silver per ton. English gas engines are being installed to operate the blast engines, which is calculated to reduce materially the fuel cost of smelting.

Mexico.—The production of base bullion in Mexico during 1901 was 79,497 metric tons, as compared with 74,944 metric tons in 1900. The principal sources of lead ore supply are the Sierra Mojada mines in Coahuila, the Santa Eulalia mines in Chihuahua, the Mapini mines in Durango, and those in the vicinity of Monterey, Nueva Leon. Since 1896, in addition to the consumption of lead ores by the smelters in Mexico, at least 150,000 tons of ore have been shipped annually to the El Paso, Texas, smelter. This large quantity of exported ore has been derived from the Sierra Mojada and the Santa Eulalia mines, mainly the former. The ores assay from 10 to 20% Pb and from 12 to 15 oz. silver per ton. The mines and the smelting plants in Mexico are well described by Joseph Struthers in the paper "Mining and Metallurgical Industries of Mexico," published in the *Engineering and Mining Journal,* October 26, 1901. The visit of the American Institute of Mining Engineers during November, 1901, which extended through the more important mining regions of the Republic, will doubtless have a very beneficial effect on the future development of the mineral industries of the country.

Spain.—The lead mines in the Linares district supply nearly 40% of the total production of Spain. The principal mines, with the depth of the deepest shaft, are as follows: the Spanish State mine, Arrayanes (350 m.), and those

operated by Taylor & Co. comprising Pozo Ancho (450 m.), Los Cumientos (440 m.), Los Salidos (450 m.), La Fortuna and Alamillos, La Tortilla, San Miguel (525 m.), and Matta Cabra (475 m.). The mining operations are carried on in a primitive manner, small wooden propped head gear and hand hoists being common. The ore is hand picked, the smaller sizes worked on jigs without previous classification, the fines pass to fine jigs and ultimately to Cornish buddles, all operated by hand power. Mr. E. Mackay-Heriot estimates the cost of hand dressing 1 cu. yd. of ore at 4·94 pesetas. The wages for the miners when sinking shafts are 4 pesetas per day, and when driving levels 3·5 pesetas; surface men receive 2·5 pesetas, boys 1·25 pesetas, smiths and carpenters 4 pesetas, engine men 3·5 pesetas, and boiler men 2·5 pesetas per day. Coal (which is of poor quality) costs 34 pesetas per ton at Linares and 37@38 pesetas at the mines. A branch railway connects the mines of Taylor & Co. with the smelter, although the transport of ore from the other mines is by donkeys and mule carts.

THE LEAD MARKETS IN 1901.

New York.—The American Smelting & Refining Co., which controls nearly the entire output of desilverized lead in the United States, was the dominant factor in the market throughout the year. Under its direction prices were fixed at a uniform rate which was regarded as fair to both producer and consumer, and it was the object of the company to maintain this schedule independent of foreign markets. As the normal supply of lead from domestic sources is greatly in excess of the home consumption, the policy outlined by the company could not be carried through without recourse to the plan of exporting the surplus or limiting the output. In the early part of the year when the quotations on the European markets were nearly on a parity with New York prices the former expedient was adopted. The foreign demand soon fell off and brought prices down to a level much below the company's schedule, so that exportation meant a loss. Arrangements were also made with the principal producers of lead ores to reduce their output, but not until royalties were promised them for the loss on contracts. Notwithstanding these expedients, the stocks held by the company had grown before the end of the year to large proportions and when the quotations on European markets fell to a point where importation to this country seemed likely, the policy was abandoned and the prices lowered. The producers of chemical and soft Missouri lead enjoyed a very prosperous year as the demand was good even at the high prices.

AVERAGE MONTHLY PRICES OF LEAD IN NEW YORK.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.
1897	3·04	3·28	3·41	3·32	3·26	3·38	3·72	3·84	4·30	4·00	2·96	3·70	3·58
1898	3·65	3·71	3·72	3·63	3·64	3·82	3·95	4·00	3·99	3·78	3·76	3·76	3·78
1899	4·18	4·49	4·37	4·31	4·44	4·43	4·52	4·57	4·58	4·58	3·70	4·64	4·47
1900	4·68	4·68	4·68	4·68	4·18	3·90	4·09	4·25	4·35	4·35	4·58	4·35	4·27
1901	4·35	4·35	4·35	4·35	4·35	4·35	4·35	4·35	4·35	4·35	4·35	4·15	4·33

London.—The lead market opened in January at £16 5s. for soft foreign and about 2s. 6d. more for English. Trade was brisk at this figure, but later on in the month there was a considerable amount of free selling on American account,

which speedily brought values down to the neighborhood of £15. The fall was so rapid that consumers were frightened off the market. When February started a steady market for a few days induced a little better demand, but on the resumption of selling, prices again broke quickly, reaching £13 10s. before the close of the month. March commenced with spirited buying on the part of prominent dealers, while American and Continental selling ceased for the time, values consequently quickly recovering to £14 10s. As soon, however, as confidence was again established, there was a renewed attack on the market by Continental holders, which drove values to £12 15s.; but with a good demand from Russia and Germany they rose to £13 5s., which was about the closing price for soft foreign, English being worth about £13 7s. 6d. April again witnessed a slump caused by free arrivals, and £12 3s. 9d. was at one time accepted. This level attracted consumers and there was a recovery to £13 5s. for forward delivery, while spot stuff being plentiful, only fetched about 10s. discount below the price of distant metals. When a fair business had been put through, the Americans again became pressing with their sales, and ere the month was out prices fell to £12 5s., and this was the price at the beginning of May. American offerings were small, and this steadied the market to £12 10s., but on a resumption of cheap offers from that side, there was a set-back of £12 2s. 6d. June opened with a dull and neglected market; prices moved fractionally round about the previous values, the month ending at £12 7s. 6d. to £12 10s. for foreign and £12 10s. to £12 12s. 6d. for English lead. July commenced with a dull tone at about £12 8s. Buyers were not inclined to commit themselves to any extent, the consequence being that prices gradually drifted throughout the month, until £11 15s. was the ruling figure, and the month ended at about this price. August showed a little better demand at the beginning of the month, but this soon fell off, and values declined to £11 10s. They ultimately recovered fractionally to £11 18s. chiefly on speculative buying, and the importers held for full prices. September witnessed a further improvement, and it was apparent that consumers were very busy. Lead for prompt delivery was somewhat scarce, and the price of short deliveries at one time reached £12 12s. 6d. They fell off by about 2s. 6d. to 5s. before October, at the commencement of which month prices declined still further to £11 5s. This level induced a good inquiry and there was a rally to about £11 10s. to £11 12s. 6d. November was a flat month, owing to heavy arrivals of European and Australian metal, which caused a decline to £11, the market practically closing at this figure. December began with a very poor demand, and with the large arrivals of metal and free selling from America and the Continent, values suffered almost daily, until at one time £10 2s. 6d. was touched for soft foreign, English being quoted £10 5s. Toward the end of the month the lower range of prices attracted a good deal more attention from consumers, who bought rather freely.

White Lead, Red Lead, Litharge and Orange Mineral.

The aggregate production of lead pigments during 1901 was slightly greater than in 1900, the increase being distributed among all varieties except litharge, of which a slightly smaller output was reported.

The production of red lead during 1901 was 13,103 short tons, valued at $1,448,550, as compared with 10,098 short tons, valued at $1,050,192, showing an increase of 3,005 tons and $398,358.

The production of white lead during 1901 was 100,787 short tons, valued at $11,252,653, as compared with 96,408 short tons, valued at $9,910,742 in 1900, an increase of 4,379 short tons and $1,341,911.

The production of litharge during 1901 amounted to 9,460 short tons, valued at $979,586, as compared with 10,462 short tons, valued at $1,067,124, a decrease of 1,002 short tons and $87,558.

There were produced during 1901 1,087 short tons of litharge, valued at $224,667, as compared with 825 short tons, valued at $100,650 in 1900, showing an increase of 262 tons and $124,017.

The detailed statistics of the production and imports of the various lead pigments are given in the subjoined tables:—

UNITED STATES: PRODUCTION OF RED LEAD, WHITE LEAD, LITHARGE AND ORANGE MINERAL.

Year.	Red Lead.		White Lead.		Litharge.		Orange Mineral.	
	Short Tons.	Value.	Short Tons.	Value.	Short Tons.	Value.	Short Tons.	Value.
1897.....	7,798	$744,709	105,804	$9,522,360	8,591	$773,190	477	$76,320
1898.....	9,160	916,000	98,172	9,391,788	7,460	710,192	658	88,937
1899.....	10,199	1,070,895	103,466	10,812,197	10,020	1,082,060	928	139,200
1900.....	10,098	1,050,192	96,408	9,910,742	10,462	1,067,124	825	100,650
1901.....	13,103	1,448,550	100,787	11,252,653	9,460	979,586	1,087	224,667

In addition to the products stated in the foregoing table, the United States Reduction & Refining Co., at Cañon City, Colo., reported an output of 2,500 short tons of "zinc-lead," valued at $150,000. This pigment is a mixture of oxidized compounds of zinc and lead made by an oxidizing smelting of lead and zinc ores in a blast furnace of special design.

UNITED STATES: IMPORTS OF RED LEAD, WHITE LEAD, LITHARGE AND ORANGE MINERAL.

Year.	Red Lead.		White Lead.		Litharge.		Orange Mineral.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
1897.....	1,386,070	$46,992	1,101,829	$48,988	60,984	$1,981	1,486,042	$67,549
1898.....	682,449	25,780	506,739	24,334	56,417	2,021	795,116	37,745
1899.....	1,021,573	43,812	584,409	30,211	55,127	3,614	1,141,387	58,242
1900.....	549,551	25,532	456,872	28,366	77,314	2,852	1,068,793	61,395
1901.....	485,467	19,370	384,673	21,226	49,306	1,873	977,644	52,479

The following table shows that the difference in price between white lead in oil and pig lead in New York in 1901 was $1·36, as compared with a difference of $1·02 in 1900. Against this must be set the difference in the price of linseed

ANNUAL AVERAGE PRICE AT NEW YORK OF CORRODING PIG LEAD AND WHITE LEAD IN OIL.

Year.	Corroding Pig Lead.	White Lead in Oil.	Difference.	Year.	Corroding Pig Lead.	White Lead in Oil.	Difference.
	Per 100 Lb.	Per 100 Lb.	Per 100 Lb.		Per 100 Lb.	Per 100 Lb.	Per 100 Lb.
1892.....	$4·05	$6·39	$2·34	1897.....	$3·64	$5·00	$1·36
1893.....	3·73	6·03	2·30	1898.....	3·79	5·08	1·29
1894.....	3·98	5·96	1·98	1899.....	4·53	5·35	·82
1895.....	3·28	5·05	1·77	1900.....	4·55	5·57	1·02
1896.....	3·03	4·90	1·87	1901.....	4·51	5·87	1·36

oil, which varied from 50c.@82c. per gal. in 1901, and from 50c.@67c. per gal. in 1900. The price of linseed oil at the beginning of 1900 was 56c. per gal.; it sold as low as 50c. in September, and reached the highest point of the year, 67c., in July. Beginning with 56c. in January of 1901, the price advanced until it reached 82c. in July, and then declined until 50c. was reached in September, closing the year at 55c. The market price for pig lead in New York opened at 4·525c. and closed at 4·125c. The former price was maintained until December 17, when it dropped to 4·125c., and continued at this quotation for the remainder of the year.

Progress in the Manufacture of White Lead during 1901.

By Parker C. McIlhiney.

The white lead industry in this country has not undergone any serious changes during the past year. The old Dutch process continues to produce the bulk of the product. It is estimated that about 92% of the white lead produced was made by the Dutch process, the other 8% being made by various quick processes. Of these the Carter process is still the most important.

Dahl's process, which is operated by W. J. Matheson & Co., of New York, was by a misprint in the last issue of The Mineral Industry, represented as resembling the Carter process, while, as a matter of fact, the process consists in treating metallic lead with acetic acid and air in such a way as to produce a solution of basic acetate of lead, which solution is then treated with carbonic acid in a separate operation, thereby precipitating the basic carbonate. The carbonic acid used is made by washing the flue gases from the boiler. The details of the operation are kept secret. The production of white lead by this process during 1901 was about 3,000 tons. The makers claim that during the past year the process has been improved so as to produce a denser lead, the specific gravity of the present product being about 6·3. The white lead now produced requires from 11 to 11·25% of oil in grinding, whereas the product formerly made required 14%, and was harder for the user to break up in oil.

The Bailey process has been taken up by the Union Lead & Oil Co., which completed a plant in Brooklyn, N. Y., early in 1902. The plant is designed to produce 12,000 tons annually. It is claimed by the company that the white lead made by the Bailey process is identical with the best Dutch lead, as it is produced by a process which is substantially the same as the Dutch except that on account of the subdivision of the lead and consequent exposure of large surfaces for corrosion, the time required for the corrosion is only three days, as compared with three months in the Dutch process. The specific gravity of the product is

given as 6·49. The company claims to have perfected the mechanical arrangements of the process in such a manner as to do away to a great extent with manual labor. The lead is run directly from the pot in which it is melted through a nozzle perforated with fine holes on to trays carried by a conveyor. The conveyor transports the trays to a corroding chamber and fills it automatically, one layer of trays above another. When the chamber is full carbonic acid is turned on from a gas holder and 2·5% acetic acid is injected with steam. The carbonic acid gas is generated by burning oyster shells and the shell lime thereby produced is stated to pay for the cost of manufacturing the gas. The carbonic acid is washed, first in a coke tower and then in a tower filled with iron sponge, both kept wet with water. The progress of the corrosion in the chamber is watched through suitable windows. The claim is made that the white lead does not require grinding at all but is simply stirred up in water and floated off. The Union Lead & Oil Co., in July, 1902, claimed to be producing white lead at the rate of 6,000 tons a year, the plant being in operation about one month.

The developments in other processes during the past year do not appear to have passed the experimental stage.

Recent Improvements in Lead Smelting.

By H. O. Hofman.

INTRODUCTORY.

New Publications.—C. Schnabel's *Handbuch der Metallhüttenkunde,* Vol. I.,[1] has appeared in a revised and enlarged edition. The general character of the book has remained the same. The chapter on lead has been enlarged from 184 to 216 pages; little, if anything, has been cut out; the additions are taken from publications which have appeared since the first edition of 1894.

C. and J. J. Beringer's "Text-Book of Assaying"[2] has appeared in its seventh edition. The favor with which this manual has been received can be judged from the fact that the first edition appeared in 1890.

Lead-Amalgams.—H. Fay and E. North, 2nd.,[3] have investigated the nature of lead amalgams. They find that there exists an amalgam, Pb_2Hg, which is soluble in and is isomorphous with lead; it therefore lowers the freezing temperature of lead when successively added to it. The compound is insoluble in mercury and therefore does not lower the freezing point of mercury when added to it. The behavior is represented in the reference by a fusibility curve, which shows that the diminished freezing points of lead all fall along a straight line, while the melting point of pure mercury remains unchanged.

New Lead Mineral.—W. H. Twelvetrees[4] describes a new mineral—Petterdite—an oxychloride of lead which was found in the upper workings of the Britannia mine, Zeehan, Tasmania. The analysis shows: PbO, 74·04%; As_2O_5, 2·6%; P_2O_7, 2·1%; Sb_2O_5, 0·5%; Cl, 20%.

Sampling Ores.—F. W. Braun & Co.,[5] Los Angeles, Cal., has put in the market the Calkins gyrating laboratory pulverizer. It consists of an iron mortar with pestle operated by turning a handle supported by an arch over the mortar. The width of the apparatus is 16 in., the height, 13 in., the diameter of the ball of the pestle, 5 in.; the net weight is 61 lb., and the weight packed for shipment, 86 lb. It is claimed that with average hard ore, 75% of it will pass through a 60-mesh sieve after one minute's grinding.

The same firm[6] has placed on the market a small laboratory hand-crusher, called "Simplex." The machine may be adjusted to produce from 2-in. to 10-mesh material. The capacity is claimed to be large.

The "Calkins Umpire Ore Sampler"[7] is a continuous sampling machine consisting of two buckets, one above the other, revolving in opposite directions. Each bucket has a central cone from which four radial partitions extend to the sides, thus giving four sectoral divisions, of which two are closed and two open at the bottom. Of 16 lb. of ore fed into the machine, 8 lb. remains in the upper bucket, 4 lb. goes into the lower bucket and 4 lb. passes as the sample into the receiver below. The machine is 3 ft. 7 in. high and weighs 55 lb.; it is easily cleaned. The claims made for it are too great, since its use must be limited,

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[1] Published by Springer, Berlin, 1900.
[2] London, Charles Griffin & Co.; Philadelphia, J. B Lippincott Co.
[3] *American Chemical Journal,* 1901, p. 216.
[4] *Engineering and Mining Journal,* July 20, 1901.
[5] *Mines and Minerals,* June, 1901, p. 526.
[6] *Mining and Scientific Press,* Dec. 7, 1901.
[7] *Engineering and Mining Journal,* April 27, 1901.

as is the case with all continuous sampling machines. An improved form has recently been patented by A. C. Calkins.[8]

The editor of the *Mining Reporter*[9] is publishing a series of articles on sampling of ores which, it is stated, are compiled from the notes of a mining and mechanical engineer. The articles are excellent and will be reviewed in detail when finished. It is hoped that a reprint in pamphlet form will appear, that this valuable contribution to the important subject may be readily accessible to all men who have to deal with ores.

G. A. Overstrom patented[10] an intermittent mechanical sampler, the details of which are not given with sufficient clearness, either in text or sketch to make them quite intelligible. Other patents are those of G. D. Potter,[11] H. E. T. Haultain,[12] and J. Scobey.[13]

The "Coronet Rolls" of F. W. Braun & Co., Los Angeles, Cal.,[14] are 2·5 in. in diameter and 1·25 in. wide, made of hardened steel and run in phosphor-bronze boxes. Both rolls are operated by one crank; a feed-plate at the front facilitates the insertion of a small button and a second plate at the back, closely wiping the bottom roll, prevents the cornet from dropping on the floor. The net weight of the machine is 75 lb. and the weight, when boxed for shipping, 85 lb.

Assay Furnace.—D. Laird patented[15] a crucible assay furnace in which the air necessary for combustion is superheated by the waste gases of the furnace.

Assay-Balance.—W. Ainsworth & Co., Denver, Colo.,[16] has placed on the market a button-balance with 4-in. beam which is said to be well adapted for quick and accurate work.

Assay of Lead Ores.—R. W. Lodge[17] criticises the statement made by the editor of the *Engineering and Mining Journal* (December 22, 1900, p. 734) that iron sulphide, formed in assaying sulphurous ores, is oxidized and fluxed. He shows, as seen below, that the amount of matte which will separate out is governed by the amount of alkali added to the charge; in fact, that with a sufficient amount of alkali the whole of the matte will be held in solution or suspension. In the assay all the sulphur, however, does not combine with the iron and alkali, part of it is oxidized and passes off into the air.

The subjoined assays A and B prove the preceding statements:—

Assay.	A.	B.	Result.	A.	B.
Ore	1 A.T.	0·5 A.T.	Slag	60 g.	65 g.
Soda	30 g.	30 g.	Matte	23·5 g.	None.
Litharge	30 g.	30 g.	Lead	24·5 g.	26·5 g.
Glass	15 g.	15 g.	Crucible, nails, flux, before fusion	685 g.	662 g.
Iron nails	4	4	Crucible, nails, flux, after fusion	665 g.	642 g.
Borax glass	10 g.	10 g.	Loss	20 g.	20 g.
			Nails. { Before fusion	64 g.	63 g.
			Nails. { After fusion	43 g.	49 g.
			Loss	21 g.	14 g.

[8] United States Patent No. 682,528, Sept. 10, 1901.

[9] *Mining Reporter*, "Notes on Sampling," Oct. 24, Nov. 28, Dec. 5, 12, 19, 26, 1901; and Jan. 16, 23, Feb. 6, 1902.

[10] United States Patent No. 674,095, May 14, 1901.

[11] United States Patent No. 679,574, July 30, 1901.

[12] United States Patent No. 680,526, Aug. 13, 1901.

[13] United States Patent No. 684,814, Oct. 8, 1901.

[14] *Engineering and Mining Journal*, April 6, 1901.

[15] United States Patent No. 671,558, April 9, 1901.

[16] *Engineering and Mining Journal*, Sept. 7, 1901.

[17] *Ibid.*, March 16, 1901.

The slag from assay A contained 6·73% and from B, 7·63% sulphide sulphur. In assay A, 8% and in B, 14% sulphur was oxidized and passed off into the air.

W. Lay[18] gives some interesting results of experiments made to study some phases of the assay of lead ores in the dry way. Fusions in a muffle with a reducing atmosphere and the following charge: ore, 10 g.; flux (sodium bicarbonate, 16 parts; potassium carbonate, 16; borax, 8; flour, 5), 30 g.; salt cover and two nails; gave the subjoined results:—

DURATION OF FUSION, FIFTEEN MINUTES.

Antimony in Ore.	Lead in Ore. Wet Analysis.	Lead in Ore. Fire Assay.	Condition of Button Resulting from Fire Assay.
%	%	%	
0·63	54·2	53·6	No evidence of brittleness.
0·90	55·7	54·7	Slightly brittle.
1·35	55·3	54·9	Buttons crack under the hammer.
1·80	54·8	54·8	Buttons crack under the hammer.
2·70	50·3	51·0	Buttons crack under the hammer.
3·60	47·7	48·5	Buttons crack under the hammer.

They show that antimony passes mainly into the lead button. Comparatively little lead is lost by volatilization. Analyses of slags of carefully conducted assays gave 0·62% Pb; the loss was also found to increase with the temperature, it being important to start at a low heat.

The following table gives the relative losses in lead by slagging and by volatilization:—

Lead in Ore. Wet Analysis.	Lead in Ore. Fire Assay.	Difference between Wet and Fire Assays in Units of Lead.	Lead in Slag. Wet Analysis.	Weight of Slag from Fire Assay. (Approximate.)	Units of Lead Accounted for in Slag.
%	%		%	Grams.	
50·9	49·2	1·7	0·62	28	1·7
52·2	50·7	1·5	0·53	28	1·5
52·7	51·1	1·6	0·47	29	1·4
62·6	61·0	1·6	0·53	28	1·5

Mechanical losses occur by spirting, when the charge is fired too quickly. These are shown in the following table.

Charges of ore and flux same as before:—

Lead in Ore. Time of Fusion, 75 Minutes.	Lead in Ore. Time of Fusion, 30 Minutes.	Lead in Slag by Wet Analysis.	Lead in Ore. Time of Fusion, 75 Minutes.	Lead in Ore. Time of Fusion, 30 Minutes.	Lead in Slag by Wet Analysis.
%	%	%	%	%	%
53·6	51·0	Average, 0·74	49·4	47·1	Average, 0·74
54·5	52·9	Average, 0·74	61·2	59·3	Average, 0·74
51·0	50·1	Average, 0·74	53·0	51·0	Average, 0·74

P. R. Robert,[19] while smelting coppery lead ores from the Standing Elk mine, Bunker Hill, Nev., assayed his ores and mattes as follows: He dissolved in nitric acid, precipitated with sulphuric acid, filtered and washed with acidulated water, dried with precipitate, removed filter and burned it, added it to the precipitate in a porcelain annealing cup, charged with five times its weight of potassium cyanide and fused. When cool, he placed the cup in water which dissolved the salts leaving behind the lead as a metallic button.

[18] *Journal of the Canadian Mining Institute*, 1901, p. 224; *Canadian Mining Review*, 1901, p. 125.
[19] *Institution of Mining and Metallurgy*, 1900-1901, Vol. IX., p. 270.

Silver and Gold Assays.—H. Nissenson[20] compared the crucible and scorification methods of assaying in use at the main laboratory of the Stolberg and Westphalen Co. for determining the silver contents in Broken Hill concentrates. These contain Pb, 66 to 68%; Zn, 6 to 8%; SiO_2 etc., 10 to 12%; S, 12 to 14%, and Ag, 23 to 26 oz. per ton. The crucible assay is carried out in wrought iron crucibles; 25 g. ore are mixed in a warm crucible with 20 g. flux (3 parts sodium carbonate; 2, borax; 1, argols), covered with 60 g. of the same flux and melted in a crucible furnace. Slag and lead are poured separately, the lead button is weighed and then cupelled. In scorifying, 5 g. of ore are mixed with 10 g. of granulated lead and covered with 25 g. of lead; 2 g. of borax and about 2·5 g. of iron wire are added to the charge. The scorification assay always gave 3·8 oz. more silver per ton than the crucible assay. Upon examining the buttons from 150 scorification- and 30 crucible-assays, the author found the scorification-assay buttons to contain 1·316% Pb, 0·556% Bi, and 0·276% Cu, a total of 2·148% impurities, and the crucible-assay buttons, 0·52% Pb and traces of Cu. The concentrates contain hardly a trace of bismuth but some was found to be present in the assay lead. The higher result of the scorification-assay is to be attributed to the impurities of the assay lead becoming concentrated in the silver button. In order to test these results, similar buttons were examined at the Mulden Works, Freiberg, Saxony, by A. Schertel,[21] who found them to contain 98·26% silver by the Gay-Lussac titration method and 98·68% silver by the gravimetric method. The filtrate of the second assay showed lead and bismuth to be present, but no copper was found.

Truchot[22] advocates the following method for determining silver in chalcopyrite: Roast the ore, dissolve in mixture of 150 c.c. of nitric acid (sp. gr. 1·42), 50 c.c. of hydrochloric acid (sp. gr. 1·18) and 100 c.c. of sulphuric acid (sp. gr. 1·58) in a dish, evaporate to disappearance of sulphuric acid fumes, add water and sulphuric acid, dissolve, transfer to breaker, dilute to 1·5 liters, add solution of 4·5 g. of salt, allow to settle in the warm over night, filter, wash, dry and burn filter, scorify the ashes, etc.

E. A. Smith[23] gives an extended review of the assaying of complex gold ores discussing the general principles involved and giving some detail instructions as to the treatment of nine different classes of ores. Basic oxidized ores are best treated by direct fusion in crucibles, special attention having to be given to the amount of reducing agent necessary, and to the addition of metallic iron for ores containing a small percentage of pyritic material. A charge for moderately basic ores (30% Fe_2O_3) is: ore, 50 g.; litharge, 40 g.; charcoal, 2·5 g.; borax, 20 g.; soda, 30 g., salt cover. One for very basic ores: ore, 50 g.; litharge, 50 g.; charcoal, 4 to 6 g.; borax, 30 g.; soda, 10 to 15 g., sand or glass, 10 to 20 g.; salt cover. With ore containing small quantities of copper or antimony, the litharge should be increased to from 60 to 70 g. With ores containing lime, alumina or zinc oxide, a mixture of 40 g. borax and 20 g. soda with 50 g. ore usually gives

[20] *Berg- und Huettenmaennische Zeitung*, Vol. LIX., 1900, p. 572.
[21] *Ibid.*, Vol. LX., 1901, 340.
[22] *Engineering and Mining Journal*, Nov. 30, 1901.
[23] *Institution of Mining and Metallurgy*, 1900-1901, Vol. IX., 315-352.

results; in the presence of barium sulphate or calcium phosphate an addition of from 10 to 20 g. fluorspar to the 50-g. ore charge may be necessary.

With very rich ores, it is necessary to clean the slag by mixing it, roughly powdered, with litharge, 30 g.; charcoal, 1·5 g.; soda, 10 g. and remelting it. Pyritic ores (containing mainly pyrites) are best first roasted and then treated as basic ores. Any loss of gold in roasting is due to want of care in conducting the operation and not to the operation itself. Direct fusion with the addition of metallic iron is justifiable only when the ores do not contain over 30% pyritic material. A slag of 50 g. quartz fused with soda will hold in solution from 10 to 12 g. iron sulphide. A good charge is: ore, 50 g.; red lead, 40 to 50 g.; charcoal, 2 g.; borax, 10 to 15 g.; soda, 40 to 50 g.; metallic iron. Oxidation with niter, which is more expeditious than roasting, ought to be applied only when the percentage of sulphurets is small. One g. iron pyrites requires 2 to 2·5 g. niter; 1 g. mispickel, copper pyrites, fahlore or blende, 1·5 to 2 g.; 1 g. antimonide, 1·5 g.; and 1 g. galena, 0·66 g. Arsenical ores are best roasted and then assayed as basic ores. An addition of a small amount of potassium cyanide to the crucible charge aids in the decomposition of arsenates. Antimonial ores are generally oxidized with niter, as roasting is connected with difficulties owing to the ready fusibility and volatile nature of stibnite. A preliminary assay will have to give the reducing power of the ore from which the amount of niter necessary can be determined.

Cupriferous ores when rich in copper (over 30%) are best assayed by the combined wet and dry methods, a suitable flux for the residue of 30 to 50 g. ore is: red lead, 30 g.; charcoal, 1·5 g; soda and borax up to 30 g. Direct fusion with ores under 30% Cu gives good results with the following charge: ore, 10 to 50 g.; red lead, 200 to 300 g.; charcoal, 1·5 to 3·5 g.; sand or glass, 10 to 25 g. For fusion after a preliminary roast, 10 to 50 g. ore are charged with red lead, 100 g.; charcoal, 3·5 g.; soda, 20 to 30 g., and borax, 15 to 30 g. With rich ores the slags should be remelted with fluxes (*see above*). Auriferous antimonial copper ores give good results with: ore, 30 g.; red lead, 150 g.; soda, 120 g.; niter, 18 g. Scorification with cupriferous ores is satisfactory, if the ores are rich enough in gold to allow the adoption of this method.

Ores with galena are best treated by direct fusion with metallic iron. Ores with blende ought first to be roasted and then treated as basic oxidized ores with an increase of the proportions of borax and soda; in exceptional cases an addition of fluorspar may be necessary.

Telluride ores ought always to be treated by direct fusion in the crucible using large amounts of litharge and ordinary fluxes. The following charge serves for most telluride ores: ore, 50 g.; red lead, 50 to 200 g. (according to the amount of tellurium present); charcoal, 1 to 2 g.; soda, 50 g.; borax, 20 g.; sand, 10 to 30 g.; salt cover. For very rich ores the following charge should be used: ore, 10 g.; red lead, 10 to 150 g.; charcoal, 1 g.; soda, 50 g.; sand, 5 to 10 g.; salt cover.

Bismuth ores are treated by direct fusion as basic ores, but in order to carry the bismuth into the slag it is necessary to have a readily fusible slag, hence comparatively large amounts of borax and soda ought to be used. A piece of iron

is added to the charge to decompose any sulphide of bismuth, as bismuth-bearing ores ought not to be roasted on account of the volatility of bismuth. Scorification is unsatisfactory.

For scorification the author recommends the following proportions:—

Character of Ore.	For One Part of Ore.		Character of Ore.	For One Part of Ore.	
	Parts of Granulated Lead.	Parts of Borax Glass.		Parts of Granulated Lead.	Parts of Borax Glass.
Antimonial	10-15	0·1 -0·5	Galena and lead minerals.	5-8	0·1
Arsenical			Iron pyrites	10-15	0·1-0·2
Basic	10	0·25-1	Siliceous	10	0·1
Cupriferous	15-20	0·1-0·2	Zinc blende	10-15	0·1-0·2
Fahlore					

Assay of Gold-Silver-Platinum Alloys.—R. Oehmichen[24] recommends the following method for separating platinum, gold and silver collected in the button in cupelling: Boil the button with sulphuric acid until the cessation of bubbles of gas shows that most of the silver has been dissolved; cool, decant the silver solution, boil the residue twice for five minutes with nitric acid (sp. gr. 1·3), wash, dry, and weigh the gold-platinum residue. If the amount of platinum is smaller than that of gold, inquart and treat with nitric acid several times, when the residue will be insoluble gold (plus any iridium that may be present). If the amount of platinum is larger than that of gold (alloy with 50 to 100 mg. of gold), dissolve in nitro-hydrochloric acid (filter off any iridium), precipitate the gold with ferrous sulphate, filter, dry, ignite, cupel adding silver necessary for inquartation, part the silver-gold button and weigh the gold. The platinum is found by difference, but may be determined by precipitating with zinc, filtering, cupelling the ashes with lead adding three times the weight of silver, dissolving the button in sulphuric acid and weighing the insoluble residue—the platinum.

Determination of Arsenic, Antimony, Tin and Bismuth.—Liebschütz[25] advocates the following method of determining arsenic, antimony, tin and bismuth in refined lead. Place 100 g. of flattened and cut-up sample in lipped beaker of 1·3 liters capacity, cover with 220 c.c. boiling water, add 100 c.c. nitric acid (sp. gr. 1·42) and 10 c.c. iron nitrate (20 g. iron to the liter); when effervescence quiets down, complete solution in one hour by warming; should any lead nitrate separate out, add water. Dilute the solution with water to one liter, add a few drops of a saturated salt solution, then neutralize, drop by drop, with caustic soda until a light red precipitate forms which darkens upon stirring. When the precipitate has settled, decant the almost clear solution into a large filter in a 5-in. or 6-in. funnel leaving the precipitate behind; fill the beaker with boiling water, stir and decant the clear solution, fill beaker again adding a few drops of caustic soda until the suspended light-red precipitate turns brick-red. In the meantime wash filter twice with hot water filling it completely and then decant solution through the filter. Add to the precipitate in the beaker a few c.c. of a 50-per cent. solution of tartaric acid and a few c.c. of hot dilute hydrochloric acid, place beaker under funnel and dissolve any precipitate on the filter with the same solvents, wash with hot water and moisten the filter

[24] *Berg- und Huettenmaennische Zeitung*, 1901. p. 187. [25] *Engineering and Mining Journal*, Aug. 10, 1901.

on and off with hydrochloric acid. Dilute solution to one liter and precipitate with hydrogen sulphide; the separation of the lead is assisted by the addition of a little ammonium sulphide. Collect sulphides on a double filter, 15 cm. in diameter, washing until all iron salts have been separated. Remove the bulk of the sulphides with wash-bottle into a 250-c.c. beaker, dissolve what remains with 20 c.c. of ammonium sulphide into the same beaker and wash with hot water. Warm the beaker for half an hour, pass solution through the same filter and wash with water containing a little ammonium sulphide. Now precipitate from the filtrate, arsenic, antimony and tin as sulphides by acidulating with hydrochloric acid. In the absence of tin, treat the washed sulphides with ammonium carbonate and titrate the dissolved arsenic with 0·01 iodine after neutralizing with acetic acid and adding starch to the faintly acid solution (1 c.c. 0·01 iodine = 0·00023 arsenic). Dissolve the antimony sulphide in 25 c.c. of hydrochloric acid at a low temperature and titrate with iodine in the presence of tartaric acid and sodium bicarbonate, using starch as an indicator. In the presence of tin, use Clark's oxalic-acid method or the electrolytic method. Place the lead and bismuth remaining on the first filter into a small dish, incinerate at a low temperature, moisten ashes with nitric acid, evaporate carefully and calcine; now add 5 c.c. of sulphuric acid, evaporate to white fumes, take up with water, filter and wash with dilute sulphuric acid. Add to the bismuth solution 12 in. of piano wire and 5 c.c. of hydrochloric acid and boil about one hour, when all the bismuth will have been precipitated as a black sponge or a black powder, if little was present. Detach the bismuth from the wire with a glass rod, decant the solution, cover the bismuth with hot water, remove the wire, decant wash-water, wash bismuth with alcohol bottle into a small porcelain crucible, remove excess of alcohol with a pipette and dry and weigh the metallic bismuth.

Analysis of Slags.—C. H. Joüet[26] publishes an outline for the analysis of slags and cinders to which reference should be made for details.

Purchasing of Ores.—The following schedule of the American Smelting & Refining Co.[27] for the purchase of silver ore is quoted to show the manner in which the value of an ore is computed. Owing to the wide extent of territory covered by this company and the resultant variable factors of freight, fuel, labor, etc., no fixed schedule is adhered to, the price paid by them for ores being usually arranged by private contract. The miner who enters into a contract with the company is required to sell to it his entire product up to a maximum of 200 tons per month which the company agrees to buy, unless it is not able, without serious loss to itself, to buy a particular combination of ores, when the miner is given the privilege to dispose of his ores otherwise during the period of suspension. The company agrees to pay for silver 95% of the value at New York; for gold, $19 per oz., if the ore contains 0·05 oz. or more per ton; and for lead 90%, either at the price agreed upon by a majority of the Cœur d'Alêne miners, or at the actual average daily New York quotation of the previous week, less 12·5c.

[26] *School of Mines Quarterly*, Jan., 1901, p. 140. [27] *Engineering and Mining Journal*, May 11, 1901.

per cwt. Excess-iron is to be paid for at the rate of 15c. per unit, and no charge is to be made for excess-silica; zinc goes free up to 10%; above that limit, 50c. is to be charged for each unit. From the gross value of the ore thus computed, $17 is to be deducted with ores, the net value of which does not exceed $20 per ton; $18·50 for ores of net value between $20 and $35; and $20 for ores of net value of $35 and over. The net value is the difference between gross value and charges. The charges are based on a railroad freight of $11 per ton on ores valued at $50 and over, and $10 on ores valued at less than $50 for full metal content. Any reduction or increase in freight rates is to be deducted from or added to the above graduated charges, as the case may be. If during the contract the price of lead becomes less than $3·50 per cwt., the treatment charge is to be reduced $1; if, on the other hand, the price of silver exceeds 65c. per oz., one-third of this excess value is to be deducted from the price of silver used in the settlement for the ore.

Importation of Lead Ores.[29]—The United States Board of General Appraisers has decided in relation to Mexican ores, carrying antimony and lead, that were treated at the Guggenheim Works at Perth Amboy, N. J., that the valuation of the ores in regard to free importation is to be based on the assays made in accordance with the Treasury regulations and not on the actual quantity of metal recovered by smelting and refining. The law requires that 90% of the metal in the ore treated in bond shall be exported.

Lead in Arkansas.—Branner[30] discusses briefly the history of lead smelting in Arkansas. The first lead smelter is said to have been erected on West Sugar Loaf Creek in 1851 or 1852. No mention is made of any lead ore being smelted in the State at present.

Lead in Belgium.—A. Firket[31] reviews the present state of the metallurgy of argentiferous lead in Belgium. There are in operation to-day four plants: Sclaigneaux, at Seilles; Bleyberg, at Montzen; Overpelt, at Overpelt and Hoboken-les-Anvers, at Antwerp. They produced in 1898, 58,390 metric tons of lead, 115,802 kg. of silver, and 233 kg. of gold. The materials treated in 1898 consisted of 548 tons of Belgian ores, 18,261 tons of foreign ores, 35,274 tons of lead-bearing residue from zinc-smelting furnaces, lead sulphate from chemical factories, metallic lead collected from the foundation flues of iron blast furnaces, and of 38,900 tons of imported argentiferous lead.

Galena ores are mixed with lead sulphate and flue-dust, and are roasted, the heat being raised sufficiently to agglomerate the roasted ore. Lead ashes are mixed with 10% lime and bricked. The two form the ores for the blast furnaces, which are small. The base bullion produced contains Cu, 0·2%; Sb, 0·7%; Ag, 46 to 58 oz. per ton: the matte, Pb, 10 to 12%; Ag, 9 to 12 oz. per ton; Zn, 4·3%; Cu, 1·9%; Sb, 1·07%; As, traces; S, 21%; Si, 4%; Fe, 48%; Ca, 1%: the slag, Pb, 1 to 1·5%; Ag, 0·5 to 0·6 oz. per ton; Zn, 6·5%; S, 2·2%; Si, 37%; Fe, 23%; Ca, 17%. The flue-dust contains $PbSO_4$, 55 to 60%; ZnO

[29] *Engineering and Mining Journal*, Dec. 14, 1901.
[30] *Arkansas Geological Survey*. Vol V., Annual Report, 1892, "Zinc and Lead." Published 1901.
[31] *Annales des Mines de Belgique*, 1901, p. 227.

and $ZnSO_4$, 7 to 10%; Ag, 8 to 11 oz. per ton. The base bullion is Pattinsonized, the rich lead with 300 oz. silver to the ton is cupelled.

The plant of *Sclaigneaux* (Seilles) has 13 roasting furnaces, 16 blast furnaces, two reverberatory smelting and four reverberatory melting furnaces, 22 Pattinsonage kettles, two cupelling furnaces, one silver melting furnace and 12 coking ovens. The following analyses give the general character of the ores treated:—

	Galena Ores.								Carbonate Ores.
	%	%	%	%	%	%	%	%	%
Pb	55·68	61·00	73·00	73·15	73·18	56·80	84·50	77·32	66·30
Ag	0·5180	(·5600	0·0300	0·0700	0·0460	0·0420	0·0250	0·0052	0·0305
Zn	15·04	10·50	7·29	1·00	5·00	5·32	0	3·60	0
Cu	0·12	0·10	0·09	0·17	0·16	0·02	0	0·02	Trace.
Fe	3·05	3·20	1·68	5·40	3·00	4 35	50	3·80	2·05
Sb	0·84	0 35	0·42	0·19	0·18	0·06	0	Trace.	0·07
As	Trace.	0	0	0	0	Trace.	0	0	0
S	18·28	16·00	14·50	12·70	14·20	20·96	12·50	14·00	0·33
SiO_2	3·18	6·10	2·00	5·10	3·60	6·70	1 00	1·20	9·70
	Lead Ashes.								
Pb	48·00	20·00	13·00	10·00	24·00	13·50	37·96	13·30	10·20
Ag	0·1600	0·0700	0·0500	0·0430	0·1250	0·0350	0·0612	0·0252	0·0204
Zn	6·00	7·00	3·50	2·50	6·50	3·50	4·41	5·00	4·00
Cu	0·25	0·27	0·22	0·15	0·25	0·19	0·98	0·30	0·25
Fe	24·03	17·78	14·40	11·77	23·80	16·52	13·26	26·90	48·00
Sb	0·12	0·02	0·02	0·05	0·10	0·05	0·30	0·50	0·60
As	0·06	0·06	0·06	0·08	0·01	0·01	0·08	Trace.	Trace.
S	2·18	3·39	2·33	2·20	2·04	2·20	1·34	2·50	2·00
SiO_2	12·75	33·87	54·66	60·00	37·80	57·80	29·87	29·30	19·50

The plant of *Bleyberg* (Montzen) has lost very much of its former importance since mining has stopped in the Bleyberg. The character of ores and lead ashes treated is shown by the subjoined analyses:—

	Galena Ores.				Lead Ashes from Bleyberg.		Bought.
Pb	62·80	60·50	70·52	72·88	13·16	24·25	32·40
Ag	0·0720	0·0061	0·0860	0·0010	0·0160	0·0316	0·0436
Zn	8·00	3·75	8·11	4·00	5·00	3·87	4·01
Fe	2·31	3·00	1·10	6·00	20·68	42·75	34·10
Cd	0	0	0	0	0	0	Trace.
Cu	0	0	0	0·10	0	0·02	0·12
S	16·26	15·00	15·15	16·00	1·84	2·26	1·58
As	Trace.	0	0·01	0	0	0	0·01
Sb	0·10	0·04	0	0	0	0	0·15
CaO	0·	1·00	1·40	0	3·50	3·66	0·84
MgO	0	0	0 10	0	0·18	0·15	0·36
SiO_2+C	0	0	0	0	44·67	18·66	19·40

Galena ores are roasted and partly agglomerated; in roasting lead ashes the heat is raised to complete fusion at the fire-bridge; both form part of the blast furnace charge. The blast furnace slag has the following composition: Fe, 40·83%; SiO_2, 29·33%; CaO, 11·4%; MgO, 1·44%; Zn, 4·25%; S, 1·86%; Pb, 0·5%; Ag, 0·0008%; As, traces. The base bullion averages: Ag, 0·11 to 0·18% (32 to 55 oz. per ton); Fe, 0·09%; Sb, 0·997%; As, 0·0012%; Cu, 0·0922%. It is softened in a reverberatory furnace and desilverized by means of the Parkes process with Roessler-Edelmann improvements, the zinc being charged with 0·5% of aluminum; the good effect of this addition is neutralized by the presence of 0·1% Cu or 0·05% As or 1% Sb. An analysis of liquated zinc-crust had the following composition: Pb, 86%; Ag, 1·7 to 2·5%; Zn, 10·5%; Cu, 0·667%; As, 0·045%; Sb, 0·4%; Fe and Cd, traces.

The silver produced at the works is ·995 fine, the difference being made up by bismuth, lead, copper and nickel. The market lead has the following composition: Pb (by difference), 99·985%; Fe, 0·01%; Sb, 0·004%; Ag, 0·001%; Zn, trace.

The plant of *Hoboken-les-Anvers* is principally a refinery in which base bullion is desilverized by the Parkes process. The bullion forms 93 to 94% of the material treated, the other 6 to 7% being lead-bearing residues from zinc smelting furnaces and zinc works. The plant has two blast furnaces, 10 softening furnaces, eight roasters, seven reverberatory smelting furnaces, 21 desilverizing kettles (17 small and four 50-ton), nine liquation pots, four retorting furnaces, five cupelling furnaces, one silver refining furnace, and one furnace for roasting coppery drosses.

The base bullion received is classed under heads A and B.

Class.	Pb.	Sb.	As.	Cu.	Ag.	Au.
	%	%	%	%	Oz. per Ton.	Oz. per Ton.
A.....	98 to 99	0·1 to 0·5	Trace.	0·1 to 0·5	29 to 87	Trace to 0·6
B.....	90 to 92	5 to 6	2 to 3	0·5 to 1·0	29 to 145	0·6 to 2·0

The following analyses show the character of the residues from zinc smelting furnaces and of the sweeps:—

	Pb.	Cu.	Sb.	As.	Fe.	Fe_2O_3.	Zn.	SiO_2.	Al_2O_3.	CaO.	Ag.	Au.
	%	%	%	%	%	%	%	%	%	%	Oz. per Ton	Oz. pr. Ton
Residues.	44	Traces.	0·2	0·6	15·9	7	6·6	28·5	7	2·3	0·05 to 0·06	Traces.
Sweeps...	0·1 to 1	0·9 to 2	0·1 to 0·3	0·5 to 1	7	30 to 35	1	50 to 60	5 to 7	1 to 5	1 to 3	0·15 to 0·18

Base bullion, A, is softened in a reverberatory furnace. The dross forms 5% of the weight of the charge and is liquated in a separate furnace, giving liquation dross with 10% copper which goes to the blast furnace; the softening skimmings average Pb, 50 to 65%; Sb, 15 to 28%; As, 0·1 to 0·5%; Ag and Au, 29 to 87 oz. per ton.

Base bullion, B, is treated in a liquating furnace giving a dross of the following composition: Pb, 67 to 70%; Cu, 14 to 16%; Sb, 2 to 4%; As, 5 to 8%; SiO_2, 4 to 6%, Al_2O_3, 0·8 to 1·2%; Fe, 0·5 to 2%; Ag, 58 to 116 oz. per ton; Au, 0·58 to 1·45 oz. per ton; it then goes into a softening furnace similar to one for bullion, A.

The skimmings from base bullions A and B are mixed with coal and melted in a reverberatory smelting furnace giving purified skimmings (to be smelted in the blast furnace for hard lead with 20 to 30% Sb) and base bullion. Zinc residues and sweeps are mixed with sand and limestone and then melted down on the hearth of a reverberatory roasting furnace before they go to the blast furnaces. The details of blast furnace work have little general interest. The following analyses show the compositions of the products: Slag—SiO_2, 30%; FeO, 35%; CaO, 12%; Al_2O_3, 10%; Pb, 1%; Zn, 10%. Matte—Pb, 20 to 25%; Cu, 25 to 30%; Fe, 30 to 35%; S, 10 to 20%; Ag, 0·1 to 0·2%. Speise—As, 15 to 25%; Cu, 25 to 30%; Fe, 30 to 40%; Pb, 10 to 15%; Sb, 5 to 10%; Ag, 0·1 to 0·2%. Base bullion—Pb, 94 to 96%; Cu, 0·2 to 2%; Sb, 1 to 2; As, 0·1 to 0·5; Ag, 87 to 145 oz. per ton. This is classed as B,

when the dross obtained in liquating has been freed from adhering lead by a separate sweating operation. It contains about 30% Cu, is ground, roasted in a reverberatory furnace and treated with sulphuric acid; the resulting copper sulphate is crystallized and sold as blue vitriol. The antimony skimmings are treated as outlined above. The details of the Parkes process are similar to the work carried on elsewhere. The following analyses deserve to be recorded. Gold crust: Au, 0·02 to 0·025%; Ag, 2 to 4%; Pb, 75 to 80%; Zn, 10 to 15%. Gold retort-bullion: Au, 0·026 to 0·03%; Ag, 3 to 5%; Pb, 95 to 96%; Zn, 0·8 to 1·5%. Zinc crust: Ag, 8 to 10%; Pb, 65 to 75%; Zn, 15 to 20%. Silver retort-bullion: Ag, 18 to 20%; Pb, 80 to 82%; Zn, 0·05 to 1%. Refined lead: Pb, 99·9903%; Ag, 0·0004%; Au, traces; Sb, 0·0030%; As, 0·0005%; Zn, 0·003%; Fe, 0·0008%; Si, traces; Cu, 0·0015%; Ni and Co, 0·0005%. Oxides from steaming desilverized lead: PbO, 83 to 87%; ZnO, 12 to 16%.

The plant at *Overpelt* treated in 1898, 1,000 tons imported lead ores, 11,600 tons leady material, and 500 tons imported base bullion. The ores before going to the blast furnaces are slag-roasted. The roaster-bed has the following composition: Pb, 33·9%; Cu, 0·85%; Ni and Co, 0·35%; As, 2·1%; Ag and Au, 0·04%; FeO, 26·30%; MnO, 1%; Zn, 6·6%; S, 1%; Al_2O_3, 4·18%; CaO, 6·8%; MgO, 0·3%; SiO_2, 16·54%. The ore-beds show: Pb, 22 to 50%; Cu, 0 to 2%; Ni and Co, 0 to 1%; As, traces to 2·5%; Ag and Au, 0·005 to 0·054%; Fe and Mn, 14 to 27%; Zn, 3 to 13%; S, 1 to 5%; Al_2O_3, 2·5 to 10%; CaO, 3 to 10%; MgO, 0 to 2%; SiO_2, 12 to 33%.

The following analyses of blast furnace products are of interest: Slag: Fe, 27·85%; MnO, 4·74%; PbO, 0·78%; ZnO, 6·32%; Cu_2O, 0·23%; S, 2·70%; CaO, 13·90%; MgO, 3·18%; Al_2O_3, 2·33%; SiO_2, 27·96%. Base bullion: Pb, 98·78%; Ag and Au, 0·14%; Cu, 0·19%; Sb, 0·72%; As, 0·08%; S, 0·08%; Fe, 0·04%. Matte: Cu, 4·85%; Ni and Co, 0·7%; Fe, 57%; Pb, 8%; Ag, 0·02%; Zn, 6·5%; S, 16·8%; Sb, 1%; As, 3%. Speise: Cu, 3%; Ni and Co, 5·1%; Fe, 55%; Pb, 1·9%; Ag, 0·017%; Zn, 2·5%; S, 3%; Sb, 5·9%; As, 23·6%.

The market lead obtained by the Parkes process is of a high grade: Pb, 99·963 to 99·987%; Ag, 0 to 0·0005%; Sb, 0·008%; As, traces to 0·003%; Bi, 0·0047%; Zn, 0 to 0·0004%; Fe, 0·0023%; Cu, 0·0005%; Ni and Co, 0 to 0·0003%.

Lead in Greece.—Cordella,[32] in a general paper on the Mineral Resources of Greece, reviews briefly the history of the smelting of lead slags and residues of the Ancients and gives a summary of the present state of the lead industry which has mainly a local interest. It may be stated that the ores treated are arsenical, giving a flue-dust with As, 35%; Pb, 27% and Ag, 8·8 oz. per ton. The smelting plant Laurion produces annually 2,000 tons of speise which is not worked up. It contains: Cu, 2%; As, 27·26%; Sb, 1·04%; Fe, 57%; Pb, 2·5%; Mn, 0·22%; Zn, 1·5%; S, 5·75%; Ni, 0·16%.

Lead-Smelting at Bunker Hill, Nev.—P. R. Robert[33] records some experiences in smelting in a blast furnace coppery lead ores from the Standing Elk

[32] *Zeitschrift fuer das Berg-, Huetten- und Salinenwesen im Preussischen Staate*, 1901, p. 365.
[33] *Institution of Mining and Metallurgy*, 1900-1901, Vol. IX., 262-266.

mine, Bunker Hill, Nev. The following partial analyses indicate their general character:—

Ore.	Pb.	Ag.	Cu.	Fe.	SiO_2.
	%	Oz. per Ton.	%	%	%
A	22·75	23·624	3·61	.....	.....
B	21·05	26·482	3·68	23·90	.....
C	17·00	37·000	4·61	17·83	23·23

The slag aimed for was SiO_2, 34%; FeO, 40%; CaO, 14%; the one actually obtained gave: SiO_2, 34·10%; FeO, 42·50%; CaO, 12·53%; MgO, 1·09%; Al_2O_3, 2·7%; PbO, 2·16%; CuO, 2·13%; S, 0·50%; K_2O,Na_2O, loss, etc., 2·29%; Ag, 0·787 oz. per ton; the bullion running 132·57 and the matte (with Pb, 63·05% and Cu, 19·6%) 111·93 oz. Ag per ton.

The water-jacket blast furnace was 36×72 in. at the tuyere-section, had four tuyeres to a side, the crucible was shallow, sloping from back to front, where there were two tap-holes, one for slag and the other for lead and matte. Lead and matte were collected in a slag pot with tap-hole at bottom and the lead tapped into moulds after the matte had solidified. The blast-pressure was 1·75 in. mercury, the coke consumption, 1 ton to 6·68 tons charge.

In a second run the bottom of the water-jacket was 9 in. below the tuyeres, at which level was also the slag-tap; the lead- and matte-tap was 3·5 in. below the slag-tap; the furnace-bottom at the back was 4 in., at the front, 18 in. below the tuyeres, thus leaving a bath of lead of 5·5 in. in the furnace. Twenty tons of ore equaling 25 tons of charge were smelted in 24 hours. One ton of Hood's Cardiff (Wales) coke, which lost 5% in handling, carried 7 tons of charge, while Crested Butte (Colorado) coke, losing 14·6% in handling, could carry only 5·5 tons of charge. A sample of copper-lead matte remaining in the furnace after blowing down gave Cu, 35·41%; Pb, 46·55%; S, 12·2%; Zn, 1·573%; FeO, 1·63% (=Fe 1·27%); Ag, 0·0253%; Mn, trace; total, 97·3963%.

Lead Smelting at Llano, Mexico.—A. Hauman[34] describes a very exceptional experience in smelting a siliceous oxide lead-copper ore at Llano, Sonora, Mexico. The composition of ores, fluxes and coke was as follows:—

	Lead-Copper Ores.	Iron Ores.	Dolomite.	Coke (Alabama).
	%	%	%	%
SiO_2	46·0	21·0	6·0	10
FeO	8·8	36·4	3·0	8
CaO	2·0	1·20	26·0	.....
MgO	.....	1·5	19·5	.....
Cu	10·0	.....	.....	.....
Pb	13·5	5·0	.....	.....
Sb	2·C	.....	.....	.....

The blast furnace was 36 in. in diameter at the tuyeres, it had a bottom metal-tap and usual slag-tap, the blast was furnished by a No. 4 Root blower. About 40 tons charge were put through in 24 hours with a consumption of 18% coke. The base bullion, which had a specific gravity of 6, showed the following composition: Cu, 55·5%; Pb, 40%; Sb, 1·8%; S and Fe, traces; Au, 5·5 oz. and Ag, 78 oz. per ton. It was very difficult to sample and to refine.

[34] *Mining and Scientific Press*, July 6, 1901.

The slag analysis gave: SiO_2, 41%; FeO, 21%; CaO, 20%; MgO, 8·6%; Al_2O_3, 0·7%; PbO, 1·3%; CuO, 0·7%. Its specific gravity ranged from 3·2 to 3·6. The cost of smelting was:—

Labor:—	Mexican currency.
Three feeders, Mexican, 8 hours, $1	$3·00
Three assistant feeders, Mexican, 8 hrs., 75c.	2·25
Three tappers, Mexican, 8 hours, $1	3·00
Six pot wheelers, Mexican, 8 hours, 75c.	4.50
Two firemen, Mexican, 12 hours, $1	2·00
Four carmen, Mexican, 10 hours, 75c.	3·00
One blacksmith, Mexican, 10 hours	2·00
One night foreman, Mexican, 12 hours	2·50
One day foreman, White, 12 hours	5·00
One assayer, White	2.50
One superintendent, White	12·00
Cost of labor, 24 hours	$41·75

	Mexican currency.
Coke, 17% of 40 tons, at $17 per ton	$115·60
Water (hauled)	25·00
Ore and flux to mine, break, and haul, at $2	80·00
Wood (for power)	3·50
Total	$265·85
Add 10% for unforeseen delays, etc.	26·60
Net total	$292·50
Net cost to mine and smelt a ton	7·31
Net cost to smelt a ton	5·21

[The U. S. money equivalents of these figures are approximately $3·65 and $2·05 a ton.]

Roasting of Ores.—In the United States Circuit Court, District of Colorado, Judge Hallett[35] decided (August 1, 1901) that the Pearce and Ropp furnaces were infringements on the Brown furnace.

Mechanical Reverberatory Roasting Furnaces.—R. F. Pearce[36] has patented a multiple-hearth mechanical reverberatory roasting furnace, similar in principle to his Turret-furnace. The main points of interest are the manner of supporting the main walls of the hearths (cantilevers and truss-rods, rising at an angle, connecting the anchor-plates with the central vertical column) and the fact that the roof of a lower hearth forms the base of the upper hearth.

B. Hall patented[37] a mechanical reverberatory roasting furnace with stationary hearth resembling in principle the Brown straight-line furnace in which the return passage of the rakes is on an over-head rail. The main differences appear to be the manner of supporting the roof and a liquid seal which is to make it impossible for gases and fumes from the furnace to enter the chamber in which run the trucks pulled by the wire rope, and for air to enter the furnace when it is not wanted.

E. P. Parnell patented[38] a continuous mechanical reverberatory furnace with stationary hearth and traveling rakes.

J. A. Bentley's patent[39] is similar in principle.

J. Roger patented[40] a mechanical feeder for roasting furnaces; a feed screw, tapering from the ore-receiving to the opposite end, is imbedded in the hearth parallel to its width; revolving, it empties an ore-hopper outside of the furnace, elevates the ore onto the hearth from below and at the same time spreads it.

Muffle Roasting Furnaces.—C. J. Best patented a muffle roasting furnace[41] with inclined stationary hearth down which the ore is to glide and undergo the desired chemical changes.

H. Carmichael patented[42] a mechanical revolving muffle-roasting furnace, consisting of an inclined revolving larger cylinder to the lower end of which is attached a smaller one heated from a fire-place. The ore fed mechanically into the upper cylinder is to give up most of its sulphur, etc., there, when passing through the lower cylinder the sulphates, etc., are to be decomposed and travel-

[35] *Engineering and Mining Journal*, Sept. 7, 1901.
[36] United States Patent No. 671,071, April 2, 1901.
[37] United States Patent No. 677,510, July 2, 1901.
[38] United States Patent No. 685,344, Oct. 29, 1901.
[39] United States Patent No. 585,903, Nov. 5, 1901.
[40] United States Patent No. 677,701, July 2, 1901.
[41] United States Patent No. 674,594, May 21, 1901. [1901.
[42] United States Patent Nos. 676,417 and 676,418, June 18,

ing beyond the fire-place in the cylinder, the ore is to cool giving up its heat to the incoming air-current.

A. P. O'Brien[43] patented some improved form of the well-known McDougal or Herreshoff furnace.

Another improved form is that of S. T. Wright.[44]

J. P. Wetherill patented[45] a muffle roasting furnace in which admission of air and withdrawal of sulphurous gases in different parts of the furnace can be regulated to suit conditions.

A. S. Partridge patented[46] a muffle furnace.

A peculiar roasting furnace was patented by G. D. Burton.[47]

J. B. Bridgewater patented[48] a door for ore roasting furnaces which slides up and down, being held in place by pins projecting from an iron casing.

A combined roaster and smelter has been patented by P. Kirk.[49]

Cooling Ores.—J. Jacobs patented[50] a car for cooling ores, containing pipes in which water or some other cooling medium is to circulate.

The Blast Furnace.—J. W. Nesmith patented[51] an improved form of his combined water- and air-jacket.[52]

A peculiar form of blast furnace has been patented by J. L. Wells.[53]

H. Kochinke[54] has published a very instructive paper on silver-lead blast furnaces. The leading facts have been brought together in the accompanying table. The furnaces are broadly of two types. The European continental furnace is circular, water-jacketed, has an internal crucible and a bottom- or siphon-tap; the American furnace is oblong, is water-jacketed, it also has the internal crucible, but always a siphon-tap. In circular furnaces the diameter at tuyeres has rarely exceeded 4·9 ft. At the Freiberg smelting works it was found that charges running low in lead could still be smelted in a furnace having a diameter of 6·6 ft.; at Braubach, Pertusola, Tarnowitz and Mazarron, with charges rich in lead, the diameter has been successfully increased to 7·9 ft. A circular furnace of 6·56 ft. in diameter represents an area of 33·82 sq. ft., an oblong furnace, 3·38×9·93 ft. has the same area. The circumference of the circular furnace is 20·7 ft., while that of the oblong furnace is 26·7 ft., the circumferences of the two furnaces of the same areas are as 3 : 4, which is, of course, in favor of the circular furnace, beside the many other advantages that it has over an oblong furnace. It should be remembered, however, that the European continental furnaces are usually charged with fritted or slag-roasted ore and large quantities of slag, while American furnaces are fed with much raw ore, often fine, and relatively little slag and lead flux. The experiment of running a circular blast furnace of large diameter in Colorado a few years ago proved a bad failure. The small diameters of tuyeres, the low tuyere-ratio and low pressure blast of European furnaces, when contrasted with American fur-

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[43] United States Patent No. 673,173, April 30, 1901.
[44] Original United States Patent No. 629,023, July 18, 1899; Re-issue No. 11,932, Sept. 17, 1901.
[45] United States Patent No. 678,078, July 9, 1901.
[46] United States Patent No. 680,613, Aug. 13, 1901.
[47] United States Patent No. 679,452, July 30, 1901.
[48] United States Patent No. 688,587, Dec. 10, 1901.
[49] United States Patent No. 688,651, Dec. 10, 1901.
[50] United States Patent No. 672,878, April 16, 1901.
[51] United States Patent No. 11,925, Aug. 6, 1901.
[52] Hofman, *Metallurgy of Lead*, Sixth Edition, p. 245.
[53] United States Patent No. 682,009, Sept. 3, 1901.
[54] *Freiberger Jahrbuch*, 1901, p. 116.

naces, is of interest. In connection with this, the low fuel consumption of the European furnaces is noticeable. Whether this be due to the easy character of the charge or to the better proportioning of blast is still an open question.

MODERN LEAD BLAST FURNACES.

Number.	Name of the Smelting Works.	Furnace.	Furnace Dimensions.				Tuyeres.		Blast Pressure.
			Height of Floor to Charging Door.	Tuyere Section.			Number.	Diameter.	
				Length	Breadth.	Area.			
			Feet.			Sq. Feet.		In.	Mm. Hg.
1	Przibram Works, Bohemia	Water-jacketed circular.	28·9	4·6	4·6	16·6	8	2·4	40
2	Victor Frederic Works, Harz Mts.	Pilz circular.	25·1	4·9	4·9	19·0	8	1·4	20
3	Freiberg Works, Saxony	Pilz circular.	18·7	3·3	3·3	8·5	8	1·2	10
4	Freiberg Works, Saxony	Pilz circular.	27·9	4·9	4·9	19·0	12	1·4	20
5	Freiberg Works, Saxony	Pilz circular.	27·9	6·6	6·6	33·8	20	1·0	30
6	Mazarron, Carthagena, Spain	Pilz circular.	22·2	6·0	6·0	28·2	8	2·0	19
7	Mazarron, Carthagena, Spain	Pilz oval.	32·8	10·0	6·0	59·1	16	2·0	19
8	Pertusola Works, Italy	Pilz circular.	23·0	7·9	7·9	48·7	16	2·0	30
9	Omaha & Grant Works, Denver, Colo.	Water-jacketed oblong	16·1	8·3	2·7	22·7	11	3·5	32
10	Philadelphia Smelting & Refining Works, Pueblo, Colo	Water-jacketed oblong	25·1	10·0	3·5	35·0	12	3·5	90
11	Pennsylvania Smelting Works, Utah	Water-jacketed oblong	24·0	11·7	3·75	43·7	14	3·5	128
12	Germania Lead Works, Salt Lake City	Water-jacketed oblong	24·0	11·7	3·75	43·7	14	3·5	128
13	El Paso Smelting Works, Texas	Water-jacketed oblong	21·0	10·0	3·5	35·0	18	3·9	32
14	Broken Hill Proprietary Works, Australia	Water-jacketed oblong	19·0	9·3	5·0	47·7	11	3·0	38
15	Broken Hill Block 14 Co., Port Adelaide, Australia	Water-jacketed oblong	18·0	16·8	5·0	66·5	18	3·5	42

Number.	Name of the Smelting Works.	Tuyere Ratio of Sq. In. of Tuyere Area to 1 Sq. Ft. of Hearth Area.	Lead in Charge.	Tons Charge in 24 Hours.				Coke.	Remarks.	
			%	Tons of Ore.	Tons of Flux and Slag.	Tons. Total	Per Sq. Ft. of Hearth Area.	%		
1	Przibram Works, Bohemia	2·16	.....	22·0	9·0	31·0	1·81	16·0	Siphon tap.	
2	Victor Frederic Works, Harz Mts.	0·51	.....	27·5	25·0	52·5	2·76	11·0	1890.	Bottom tap.
3	Freiberg Works, Saxony	1·06	12–15	25·0	24·0	49·0	5·77	9·5	1899. (*a*)	Bottom tap.
4	Freiberg Works, Saxony	1·24	12–15	30·0	27·5	57·5	3·08	9·0	1872.	Bottom tap.
5	Freiberg Works, Saxony	0·46	12–15	60·0	40·0	100·0	2·96	8·5	1896.	Bottom tap.
6	Mazarron, Carthagena, Spain	0·89	.....	55·0	55·0	110·0	3·90	(?)	.....	Bottom tap.
7	Mazarron, Carthagena, Spain	0·97	.....	67·5	67·5	135·0	2·59	(?)	.....	Bottom tap.
8	Pertusola Works, Italy	1·08	33	116·0	64·0	180·0	3·70	8·5	1898.	Bottom tap.
9	Omaha & Grant Works, Denver, Colo.	4·66	13	40·0	20·0	60·0	2·64	20·0	1899.	Bottom tap.
10	Philadelphia Smelting & Refining Works, Pueblo, Colo	3·57	9–11	.....	.....	100·0	2·86	13·5	1897.	Siphon tap.
11	Pennsylvania Smelting Works, Utah	3·08	18–20	75·0	70·0	145·0	3·32	11·5	1896. (*b*)	Siphon tap.
12	Germania Lead Works, Salt Lake City	3·08	11	.....	.....	170·0	3·89	12·5	1897.	Siphon tap.
13	El Paso Smelting Works, Texas	4·44	12	40·5	29·0	69·5	1·99	13·0	Carbonate ore.	Siphon tap.
14	Broken Hill Proprietary Works, Australia	1·63	9–15	.....	.. ...	70·0	1·47	12·5	Mainly carbonate ore.	Siphon tap.
15	Broken Hill Block 14 Co., Port Adelaide, Australia	2·61	20–30	.....	.....	100·0	1·50	11·0	75% roasted ore.	Siphon tap.

(*a*) Movable tapping hearth. (*b*) 66·6% roasted sulphide ore and 33·3% raw carbonate ore.

J. H. Rodda[55] suggests that to obviate the difficulties encountered in smelting silver-lead ores rich in zinc, arsenic and antimony, the siphon- or bottom-tap, should be closed and an external crucible attached with trapped blast to the front of the furnace and the melted masses allowed to flow continuously into the fore-hearth, where they can separate and be tapped.

[55] *Engineering and Mining Journal*, Sept. 7, 1901.

Blast-furnace Elevator.—Clemmer[56] gives an illustrated description of an elevator for smelting plants. It is designed to raise 6,000 lb. to a height of 19 ft. 8 in. with steam, water or air at a pressure of 60 lb.

Blast-furnace Stack.—W. Magman[57] describes and illustrates the wooden smelter stack built in six weeks in 1897 by the Compañia Minera de Peñoles at Mapimi, Durango, Mexico, at a cost of $10,000 (Mexican). A brick stack would have cost four times as much. The stack is 180 ft. high and 10 ft. square, and is constructed of ordinary 1-in. matched flooring lumber and lined on the inside with No. 22 corrugated roofing iron. The bracing is built mainly of 4×6-in. and 6×6-in. timber, some 8×8-in. timber being used in some parts.

Graphical Calculation of Blast-furnace Charge.—E. A. Hersam[58] gives a simple and easy method for the use of the tri-axial diagram in the calculation of slags which will be of interest to those who prefer graphical to algebraic methods of calculating charges.

Rotary Blowers versus Blowing Engines.—The replacement of rotary pressure blowers by blowing engines for furnishing the necessary air to lead blast furnaces and matting furnaces is receiving much consideration.[59] In former times with a blast pressure of from 8 to 12 oz., rotary pressure blowers of the Blake and Root type did very satisfactory work. When the pressure was raised to 40 oz. and sometimes even to 48 oz., the matter assumed a different aspect.

A. Raht,[60] for example, tested the volumetric efficiency of a rotary pressure blower by closing the discharge opening ("closed discharge"), connecting a pressure gauge with the closed delivery-pipe and gradually speeding up the blower. The gauge could be made to register only 10 lb. pressure, thus showing that the blower would not deliver air against a pressure of 10 lb. At 4 lb. pressure, the loss in blast appeared to be about the same as at 10 lb. Manufacturers advise the use of piston blowing engines for pressures exceeding 5 lb. Hixon[61] does not believe that the field of the blowing engine proper exists below 5 lb. Vezin[62] maintained several years ago that rotary pressure-blowers were not any cheaper than cylinder blowing engines with pressures of from 1 to 2 lb. on account of the back leak or slip. Notwithstanding the criticisms of specialists, rotary pressure blowers of unusual sizes are being built to meet the increasing demands, because they are believed to be cheaper. Thus a furnace[63] 42×140 in. to be driven under a pressure of 40 oz. has recently been provided with a No. 10 blower, to be run at 100 revolutions per minute, which with a displacement of 300 cu. ft. per revolution corresponds to 30,000 cu. ft. per minute. The force required to drive the blower approximates 400 H.P.

Channing[64] gives an example of a piston-blowing engine and a rotary pressure

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[56] *Engineering and Mining Journal*, June 22, 1901.

[57] *Mining and Scientific Press*, June 29, 1901.

[58] *Transactions of the American Institute of Mining Engineers*, February, 1901.

[59] *Engineering and Mining Journal*, 1901: S. E. Bretherton, April 13, August 24; Editor, April 27; J. P. Channing, June 8; H. W. Hixon, July 20.

[60] *Ibid.*, April 13, 1901, p. 458, col. 2, in article by Bretherton.

[61] *Ibid.*, July 20, 1901.

[62] *Transactions of the American Institute of Mining Engineers*, Vol. XXVI., p. 1095; Hofman, *Metallurgy of Lead*, Sixth Edition, p. 250.

[63] *Engineering and Mining Journal*, April 27, 1901.

[64] *Ibid.*, June 8, 1901.

blower recently erected to supply two copper blast furnaces. The engine of the Tennessee Copper Co. has two air tubes 57×42 in.; the steam cylinders, of the Corliss type, are 13 and 24 in. by 42 in. The blast pressure is 2·5 lb. per sq. in. The smelter of the Santa Fe Gold & Copper Mining Co. has recently installed a No. 8 blower directly coupled to a 14×32-in. Corliss engine. The blast pressure being 12 oz. to the sq. in.

Utilization of Blast-furnace Slags.—At the Chemical Works "Marienhütte," Langesheim, Lower Harz Mountains,[65] the lead blast-furnace slags, rich in zinc and baryta, are treated in the following way: the slag is pulverized in a ball mill, mixed with calcium chloride and melted down at about 1,200°C. under oxidizing conditions in a reverberatory furnace. The melted mass, when cold, is pulverized in the ball mill and leached with water. There results a solution of barium chloride nearly chemically pure and a residue of calcium sulphate with some silicates of zinc and iron. The residue, while still moist, is transferred into lead-pans and treated with sulphuric acid of 50°B.; it soon becomes hot, turns white and solidifies. It is now mixed with calcium chloride, pulverized in a ball mill, and heated to 500°C., chlorides of zinc and iron are formed, the iron chloride being decomposed ($2FeCl_2+2H_2O+O=Fe_2O_3+4HCl$), the hydrochloric acid set free being used to prepare calcium chloride from limestone. The mixture is finally treated with water giving a solution of zinc chloride containing a little iron and a residue, consisting mainly of calcium sulphate and ferric oxide. This is ground, dried and sold as red paint.

Dust-Catcher.—Cavallier[66] constructed a wet dust-catcher which collects the dust from the iron blast furnace at Pont-à-Mousson, France. In 24 hours 350,000 cu. in. of air pass through the dust catcher and deposit about 630 kg. of flue-dust.

Condensation of Flue-dust.—E. Balbach, Jr., patented[67] a condenser for flue-dust and fumes. It has the form of a tower with vertical partition walls that force the gas-current to zigzag up and down through the tower; at right angles to these deflection walls are air-cooled divisions connected by pipes that the gases in their zigzag passages may give up their heat and allow the fumes to settle out.

Briquetting Flue-dust and Fine Ores.—The Chisholm, Boyd & White Co.[68] state that 50 of their roller- and plate-mould briquetting machines[69] were in operation in March, 1901, and that during an 18-months' run the cost of briquetting at one plant was 62·5c. per ton, which figure included repairs of plant, power, labor, bond and automatic carrying of briquettes to the furnace floor. The briquettes are 2·5 in. in diameter and 4 in. high. The machine has a capacity of 80 briquettes per minute and requires 35 H.P. for operating the press and the auxiliary machinery which slacks the lime, separates the milk of lime from uncalcined particles of limestone, pumps it into a mixer into which the material to be bricked is fed automatically, incorporates the lime and delivers the prepared mixture to the press. The combined output of the briquetting

[65] *Oesterreichische Zeitschrift fuer Berg- und Huettenwesen*, 1901, p. 27; and *Chemiker Zeitung*, 1900, p. 502.
[66] *Berg- und Huettenmuennische Zeitung*, 1900, p. 565. [68] *Engineering and Mining Journal*, March 2, 1901.
[67] United States Patent No. 676,380, June 11, 1901. [69] See Hofman, *Metallurgy*, Sixth Edition, p. 404.

plants installed by this company in the United States and foreign countries is about 3,000,000 tons annually. Among the well-known lead and copper smelting companies using the White machine are: American Smelting & Refining Co. (10); La Gran Fundicion Central Mexicana (3); Northport Mining & Smelting Co. (2); Mountain Copper Co. (3); and many others. In all about 50 plants are using these presses for briquetting various materials.

The Henry S. Mould briquetting plant[70] has made considerable progress since it was first built a few years ago. Among the numerous smelting plants using the White briquetting press, which is manufactured by this company are: American Smelting & Refining Co.; Bingham Consolidated Mining & Smelting Co.; Anaconda Copper Co.; Nichols Chemical Co.; Greene Consolidated Copper Co., at La Cananea, Mex.; Old Dominion Copper Mining & Smelting Co.; Backus & Johnson Co., Lima, Peru; Compañia Minera de Piñoles, Mapimi, Mex.; Mount Lyell Mining & Railroad Co., Tasmania, etc. The combined annual output of the briquetting plants using the White briquetting press amounts approximately to 1,000,000 tons of briquettes.

Briquetting machines have been patented by R. Schorr[71] and J. T. Davis.[72]

Desilverization of Base Bullion.

Parkes Process.—A. Schertel[73] furnishes an interesting analysis of a felt-like metallic scaly mass of a bright copper-color which was found imbedded near the tap-hole of a softening furnace, the hearth-material of which consisted of a

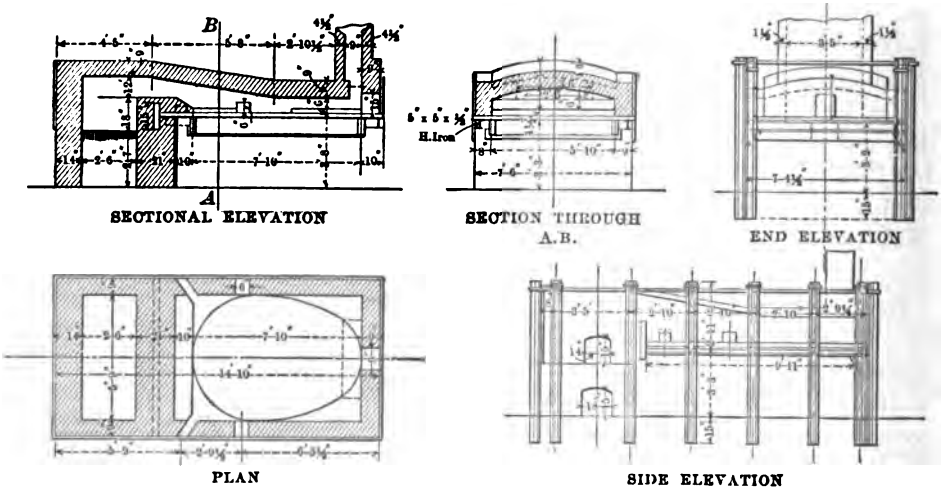

Fig. 1.—Cupellation Furnace with Water-cooled Hearth.

mixture of raw and burnt fire clay rammed down firmly. The scales, which could not be entirely freed from hearth-material, showed the following composition: Cu, 59·75%; Pb, 33·46%; Sb, 0·37%; Ni, 0·65%; Ag, 0·13%; Au, 0·0235%; total metal, 94·3925%; clay, 5·6%. Calculating the percentage

[70] *Engineering and Mining Journal*, Nov. 30, 1901.
[71] United States Patent No. 667,254, Feb. 5, 1901.
[72] United States Patent No. 678,859, July 16, 1901.
[73] *Freiberger Jahrbuch*, 1900, 59. 1901.

on the basis of metal alone, gives: Cu, 63·31%; Pb, 35·45%; Sb, 0·39%; Ni, 0·69%; Ag, 0·137%; Au, 0·025%. Now the base bullion, freed from copper-dross in a liquation furnace, contains 0·06 to 0·10% Cu before it is charged into softening furnace, and this amount grows to 0·12 to 0·15% by the removal of the arsenic and antimony. That such small amounts should separate out seems remarkable. Traces of nickel and gold are seen to have been concentrated in the scaly product in a much more remarkable degree even than copper.

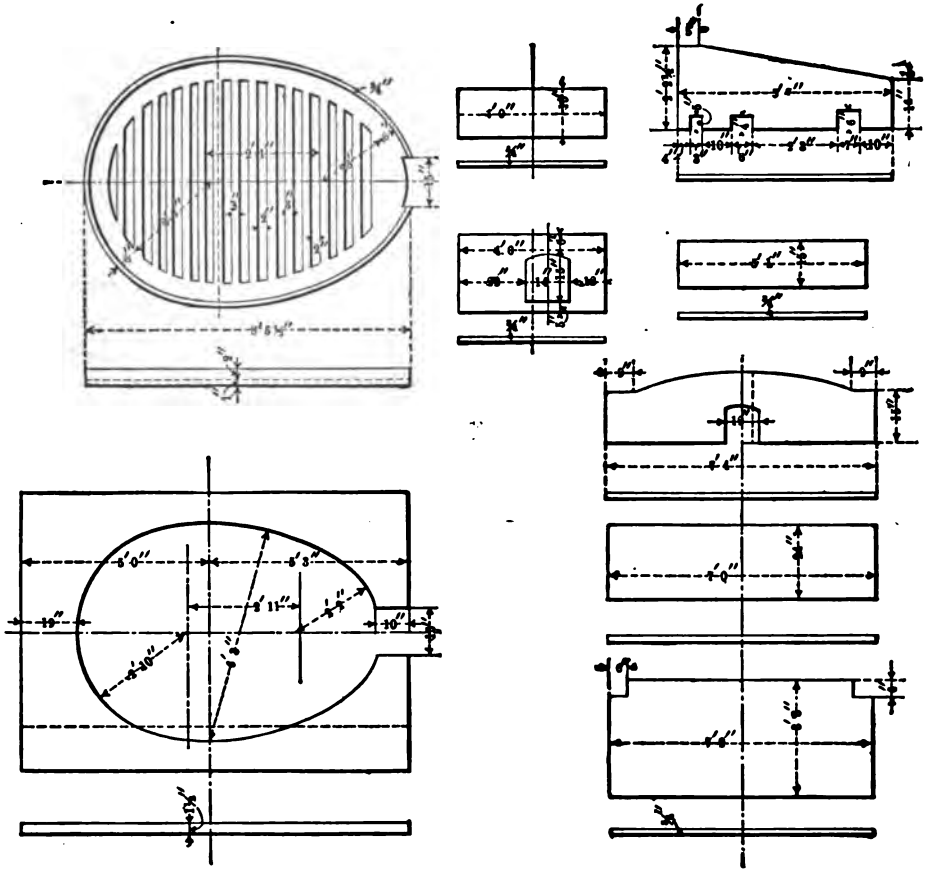

FIG. 2.—CUPELLATION FURNACE. DETAILS OF HEARTH CONSTRUCTION.

Electrolytic Refining.—A. G. Betts[74] patented a process for the electrolytic refining of base bullion in which lead fluosilicate, $PbSiF_6$, is said to be the electrolyte. This salt is claimed to be soluble in acid solution and to show a high conductivity, also no lead is said to be deposited on the anode as peroxide when it is used.

Cupellation.—E. A. Weinberg[75] describes, as shown in Figs. 1, 2 and 3, a water-cooled test for concentrating retort bullion. One peculiarity of the water jacket

[74] *Electrical World and Engineer*, 1901, p. 260.
[75] *Transactions of the Australasian Institute of Mining Engineers*, 1901, Vol. I., 167.

is that the inside is 0·375-in. copper plate and the outside 0·375-in. mild-steel plate, the breast is of brass. The author adopted this construction, as he had found that mild steel was soon corroded when the litharge, after having begun to eat into the filling, came in contact with it, while a copper test-ring had stood for over five years. The test, oval in shape, is 7·5 ft.×5 ft. 5 in. inside. The filling is made of five parts of cement and one part of sand, the bottom and sides are made 4 in. thick. The test which is run into position on a truck and held in place by jack-screws, holds 4,265 lb. of metal when new, and as

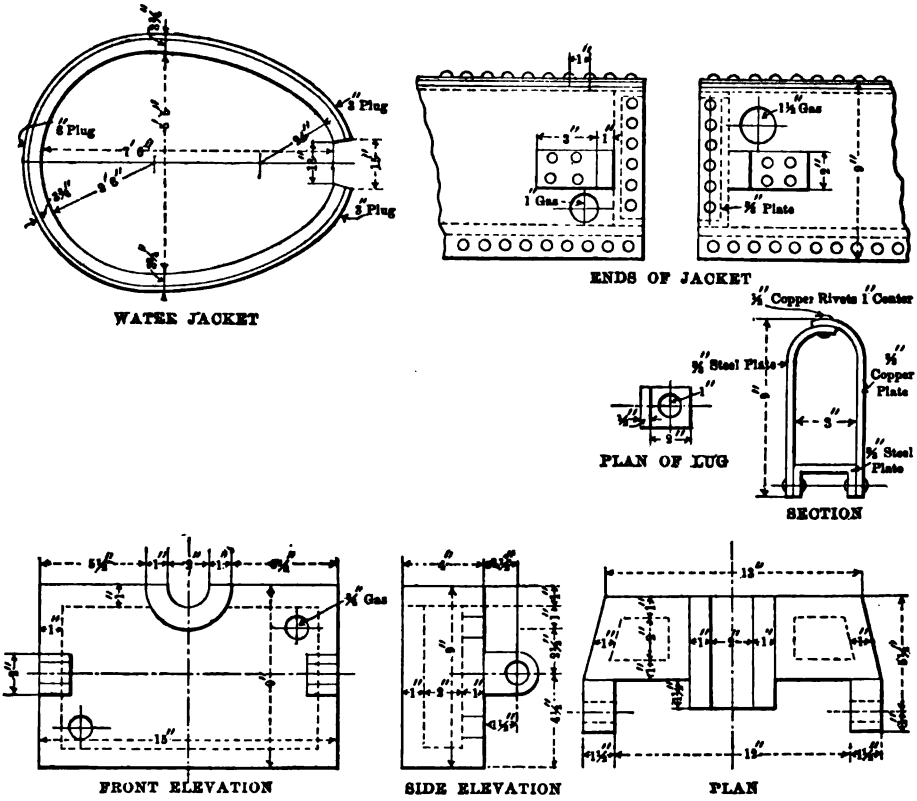

FIG. 3.—CUPELLATION FURNACE. DETAILS OF CUPEL CONSTRUCTION.

much as 4,700 lb. when worn. Its life is three months when used for cupelling alone and two months when treating all sorts of drosses.

LEAD POISONING.

F. Blum[76] published in pamphlet form a summary of what has been found useful in combatting lead poisoning, supplementing it with his researches. Lead ores, the author says, ought not to be allowed to become dry before it is absolutely necessary; this is especially the case with carbonate ores which are more harmful than sulphides or sulphates. Sulphurous gases which are so common around

[76] *Untersuchungen ueber Bleivergiftungen und ihrer Verhuetung in Industriellen Betrieb*, Frankfurt-a-Main, 1900.

lead plants treating sulphide ores are harmful. This is contrary to generally accepted ideas, but the author, by synthetical experiments, has shown this to be a fact. In dusty places, nose and mouth are best protected by a sponge, by cotton or some other respirator as long as this does not contain any valves. Men engaged in lead work ought to be watched to see whether lead is having a bad effect or not, as some men stand lead fumes and dusts for years, while others feel the bad effects in weeks; the latter men ought, of course, to give up lead-work at once. When a man has become leaded and is apparently well again, it is advisable to keep him at some other work for several weeks, for if he returns at once to his regular occupation, he is liable to be taken down in a very short time. Alcoholic beverages and acid foods are to be avoided, while glutinous foods ought to be taken frequently.

At present, no remedy is known which will assist to rid the body of the lead that has got into it. Potassium iodide, which has always been recommended, has been found by Dr. Blum to have no effect whatever. Of course cleanliness and good ventilation are the principal means of preventing men from becoming leaded. A supplement contains the experiments and opinions of W. H. Hutchings, manager of the lead works of Cookson & Co., Newcastle-upon-Tyne, which have a daily capacity of 200 tons white lead and 50 tons red lead. In 1898 there was only a single case of lead poisoning, and a light one at that; in 1899 there were five, and in the first six months of 1900, none at all.

Hutchings finds that lead sulphide and sulphate are practically harmless, lead oxide is poisonous and carbonate exceedingly so. He believes, contrary to the opinion generally held, that lead enters the human body only through mouth and nose and not through the pores of the skin. As to protective measures the best of ventilation and cleanliness of floors are essential. The only remedy that has so far proved somewhat efficacious is the use of lozenges made of sulphur, sugar and peppermint, containing 0·5 grain of sodium sulphide; the sulphur and alkaline sulphide converting the lead into harmless sulphide.

MAGNESITE.

THE production of magnesite in the United States continues to be derived solely from California, and in 1901 the output amounted to 13,172 short tons, valued at $43,057, as compared with 2,708 short tons, valued at $11,832 in 1900. The reported production in 1901 was comprised of 3,112 short tons of crude magnesite and 4,726 short tons of calcined magnesite, which latter is equivalent to 10,060 short tons of the crude product, making a total of 13,172 short tons.

PRODUCTION OF MAGNESITE IN CALIFORNIA.

Year.	Crude.			Calcined.		Crude Equivalent of Calcined. Short Tons.	Total Crude.	
	Short Tons.	Value at Mine.	Per Ton.	Short Tons.	Value at Works.		Short Tons.	Value.
1897.....	379	$1,516	$4·00	764	$10,700	1,528	1,907	$7,628
1898.....	200	800	4·00	1,013	14,200	2,155	2,355	9,420
1899.....	400	1,200	3·00	800	12,200	1,600	2,000	7,600
1900.....	469	1,876	4·00	1,013	15,900	2,239	2,708	11,832
1901.....	3,112	16,725	5·37	4,726	26,332	10,060	13,172	43,057

The very considerable increase in the production of magnesite in the United States during 1901 resulted from its extensive use as a refractory lining for open-hearth furnaces and converters in the steel industry, for lining rotary kilns used in the manufacture of Portland cement, and as a non-conducting covering for boilers, steam pipes, etc., to prevent the loss of heat. There is also a considerable quantity utilized in the manufacture of carbon dioxide gas for carbonating beverages. The carbon dioxide gas is produced from magnesite by treatment with sulphuric acid or by the application of heat alone; in the former case magnesium sulphate ($MgSO_4 7H_2O$) or Epsom salts is made as a by-product, the production of which during 1900 is estimated at 8,000,000 lb. Magnesite bricks for the refractory lining of furnaces are made in this country by the Fayette Manufacturing Co., at Layton, Pa., and by the Harbison & Walker Co., of Pittsburg, Pa. The latter company is equipped to manufacture 3,000,000 brick annually and has furnished the following analyses of its products: Grecian magnesite brick: CO_2 0·14%, Al_2O_3 0·686%, SiO_2 3·2%, Fe_2O_3 0·3%, CaO 1·9%, and MgO 93·876%. Styrian magnesite brick: CO_2 0·04%, Al_2O_3 0·98%, SiO_2 3·4%, Fe_2O_3 5·1%, CaO 2·8%, and MgO 87·8%.

The importation of crude and calcined magnesite during 1901 was 33,461 short tons, as compared with 28,821 short tons in 1900, the supply being derived

mainly from Greece and Styria. No statistics are available for the importation of magnesite bricks, which is of considerable importance. The greater part of the consumption of magnesite in the United States is derived from foreign sources.

Austria.—The plant of the Veitscher Magnesitwerke Act.-Ges., at Veitsch, Styria, employs 1,500 men and has a capacity of producing 100,000 tons of finished product, which embraces raw, burnt and sintered magnesite in large and small lumps and finely ground, mortar, burned bricks and other shapes for iron and steel furnaces, cement kilns, etc., pipes, crucibles, tuyeres for basic Bessemer converters, etc.

The following analyses of calcined magnesite and magnesite bricks have been furnished by Paul Mansfeld, of Budapest, Hungary:—

	MgO.	CO_2.	Fe_2O_3.	SiO_2.	Al_2O_3.	CaO.	Loss.	P_2O_5.	Undetermined.
	%	%	%	%	%	%	%	%	%
Calcined magnesite....	90·42	0·46	5·02	0·17	2·38	1·50	0·05	.....	.....
Calcined magnesite.....	90·95	.....	6·50	0·50	.....	1·70	0·35	.....	.....
Calcined magnesite.....	91·50	.....	6·90	.....	.....	.....	.....	.....	.....
Mansfeld magnesite bricks.....	91·52	.....	6·05	0·35	.....	2·10	.....	.....	.....
Styrian magnesite bricks.....	89·00	.....	7·60	3·45	1·30	3·90	0·20	0·08	0·47

A. Vesterberg has made an elaborate study on the effect of heat on magnesite and dolomite which shows that the magnesium carbonate is present in the latter as a double salt of magnesium and calcium $(Mg,Ca)CO_3$.

Greece.—Two companies, one English and the other Greek, are now operating the magnesite mines of Eubœa, the Greek company shipping both the raw and calcined magnesite from the small seaport of Katunia. Until recently primitive wood-fired kilns were employed for calcining the ore, which required a large quantity of fuel; recently, however, modern shaft calciners have been constructed and a local lignite is used to advantage both for cost and working. Magnesite when completely calcined falls to powder when moved and chokes the lower or cooling portion of the ordinary kiln, preventing the access of air and heated gases necessary for calcination. The modern furnace is especially constructed to overcome this result. From 16 to 20% of lignite is required for the complete calcination of the magnesite. Small pieces are best calcined in a double-hearth reverberatory furnace with the flame in direct contact with the freshly charged magnesite on the upper hearth, the operation being completed on the lower and hotter hearth. Pure magnesite from Eubœa is highly refractory and sinters only at a very high temperature, and for the manufacture of magnesite bricks it is necessary to add a suitable binding material. The Greek company, at its works at Mantudi, uses a small proportion of serpentine in its mixture, and produces a very hard and dense brick by burning at a temperature of 1,400°C. in a regenerative furnace of the Siemens type. Their product is consumed in metallurgical works of the United States and elsewhere.

Russia.—An analysis of a sample of magnesite from a large deposit recently discovered in the Department of Ufa, Southern Urals, gave MgO 46%, CaO 0·85%, Fe_2O_3 and Al_2O_3 1·62%, SiO_2 0·3%, and CO_2 51·23%; total 100%. This magnesite is to be used for the manufacture of magnesite bricks at the recently erected works near Zlatoonst.

MANGANESE.

THE production of manganese ores of all grades in the United States during 1901 is given in the subjoined table, which does not include the manganiferous iron ores of Colorado and other Western States consumed as a flux in silver-lead smelting, although account is taken of that portion sold to steel makers for the manufacture of ferromanganese and spiegeleisen. The average manganese content of the ores from the different States is shown in the second table. For details of the American consumption and supply, reference may be made to the article by Alfred A. Wheeler in THE MINERAL INDUSTRY, Vol. VIII. The composition and occurrence of the ores of manganese have been fully set forth in the preceding volumes.

The subjoined table shows the relative production for the years 1897 to 1901 of the high-grade ore from Arkansas, California, Georgia, Tennessee and Virginia; of Colorado ores used for steel making purposes; of the low-grade ores from Michigan and Wisconsin, and of the manganiferous residuum from the zinc oxide works of New Jersey and Pennsylvania.

STATISTICS OF MANGANESE ORE IN THE UNITED STATES. (IN TONS OF 2,240 LB.)

Year.	Production.											Imports.		Consumption.	
	Arkansas.	California.	Colorado	Georgia.	Michigan and Wisconsin.	New Jersey.	Tennessee.	Virginia.	Elsewh're	Totals.		Tons.	Value.	Tons.	Value.
					(a)	(b)				Tons.	Value.				
1897	4,430	450	18,600	992	80,261	50,000	190	2,408	c1,300	158,600	$328,176	89,574	$340,945	198,174	$669,121
1898	2,775	398	17,792	2,477	112,318	47,470	1,250	3,507	.....	187,782	416,627	114,885	831,967	302,667	1,948,594
1899	855	268	29,161	1,623	58,702	53,921	80	3,626	75	148,256	306,476	188,349	1,584,528	331,605	1,891,004
1900	51	231	45,791	1,058	75,360	91.748	*Nil.*	3,968	.....	218,222	461,994	256,252	2,042,361	474,474	2,504,355
1901	91	610	62,385	4,074	512,084	52,311	400	4,275	2,565	638,795	1,644,117	165,722	1,486,573	804,517	3,130,690

(a) Manganiferous iron ore. (b) Franklinite residuum. (c) Vermont manganiferous iron ore.

MANGANESE PRODUCTION AND CONSUMPTION OF THE UNITED STATES ON A BASIS OF 50% MN CONTENT. (IN TONS OF 2,240 LB.)

Year.	50% Ores from Ark., Ga., Va., Cal. & Tenn.	30% Ore from Colorado.	12% Ore from New Jersey	7% Ore from Mich. and Wisconsin.	Equivalent Total Tonnage of 50% Ore.	Imported Ores of 50% Grade.	Total Consumpt'n of 50% Grade & Equivalent.	Per Cent. of Imp'd Ore.
1897.....	8,440	18,600	50,000	80,261	42,836	89,574	82,310	48·1
1898.....	9,909	17,792	47,470	142,318	51,295	114,885	166,180	69·1
1899.....	6,397	29,161	53,921	53,702	44,353	188,349	232,702	80·1
1900.....	5,833	45,791	91.748	75,360	65,368	256,252	321,620	79·7
1901.....	9,450	62,385	52,311	512,084	a 131,127	165,722	296,849	55·8

(a) Not including 2,500 tons from Utah and small quantities aggregating 65 tons from Alabama, Missouri and North Carolina, of which the manganese content was not reported.

The price of manganese ore is determined by the Illinois Steel Co., according to the following schedule which is based on ores containing not more than 8% SiO_2 and 0·1% P. Deductions are made of 15c. per ton for each 1% of SiO_2 in excess of 8%, and of 1c. per unit of manganese for each 0·02% P in excess of 0·1%. Ores delivered at the works of the company, South Chicago, Ill. Settlements are based on analysis of samples dried at 212° F.; the percentage of moisture in the samples as taken being deducted from the weight.

Tenor in Mn.	Price per Unit.		Tenor in Mn.	Price per Unit.	
%	Fe.	Mn.	%	Fe.	Mn.
Over 49	6c.	28c.	37 to 40	5c.	24c.
46 to 49	6c.	27c.	34 to 37	5c.	23c.
43 to 46	5c.	26c.	31 to 34	4c.	22c.
40 to 43	5c.	25c.	28 to 31	4c.	21c.

Schedules of prices offered by the Carnegie Steel Co. differed but slightly in detail from the above, being about 1c. per unit lower for manganese.

The imports of manganese iron ore during 1901 were 165,722 long tons, valued at $1,486,573, as compared with 256,252 long tons, valued at $2,042,361. This large increase is attributable to the low price of foreign spiegeleisen and ferromanganese, large quantities of which were used by the steel makers in preference to the purchase of manganese ores and the manufacture of the products themselves.

Metallic manganese is now being manufactured at Essen, Germany, by the Goldschmidt process of aluminum reduction. Its relatively high cost, as compared with ferromanganese, however (about 10 to 1), limits its use mainly for the manufacture of copper alloys. The pure metal oxidizes very slowly in the air and alloys readily with other metals. Manganese-iron-titanium alloys have been made containing as high as 40% Ti, but these are so refractory that an alloy of from 20 to 25% Ti is generally used. The presence of titanium in iron or steel even in quantity not exceeding 0·2% produces a very tough, fibrous structure to the metal, and as this element will unite much more readily with manganese than with iron, a manganese-titanium alloy containing from 30 to 35% Ti has been used with good results in place of ferrotitanium. Furthermore, the manganese alloy dissolves more readily in the molten iron than the iron alloy.

Colorado.—According to the report of the Hon. Harry A. Lee, the production of manganiferous iron ores in Colorado during 1901 was derived from Lake County solely, and amounted to 68,500 long tons of an average composition of from 28 to 30% Mn, 22 to 24% Fe, 3 to 4% SiO_2, 0·035 to 0·05% P and 4 to 10% H_2O. About 65% of the output was shipped to the Illinois Steel Co., Chicago, Ill., and 35% was used in Colorado for the manufacture of ferromanganese and spiegeleisen. A large quantity of manganiferous iron ores was consumed during the year as a flux by the silver-lead smelters, which is not included in the statistics of production.

Georgia.—(By T. L. Watson.)—The manganese ore deposits of Georgia have been continuously worked for many years, and during the early development the ore was marketed chiefly in England; at present, however, the entire output is

consumed in the United States, where it is used principally for the manufacture of ferromanganese and spiegeleisen, and to a less extent in bleaching purposes.

Of the manganese oxides which occur in the deposits, pyrolusite and psilomelane greatly predominate, with some manganite and braunite, and in places considerable wad (the earthy oxide). These oxides usually occur admixed in varying proportions, and cannot always be separated. The distribution of the workable ores is limited chiefly to Bartow, Floyd and Polk counties. In Bartow County the Cartersville district has furnished almost the entire manganese output of the State. In 1901 considerable manganese was mined and shipped from the Cave Spring district in Floyd and Polk counties, near the Alabama State line. A very promising area has more recently been opened to the east of Rome, in Floyd County, near Lindale. Small amounts of the ore have been mined from time to time at several other places in the more northwestern portion of the State. No workable deposits of manganese have as yet been opened beyond the limits of the Paleozoic group, although limited occurrences of the manganese oxide are known at many points in the Crystalline area.

The manganese ore in the workable areas occurs chiefly as lumps and masses, mostly in the form of irregular pockets, small veins and stringers, and rarely as true beds. The ore is embedded in the heavy mantle of residual decay derived from the Knox dolomite, Beaver limestone and Weisner quartzite (Chilhowee sandstone of Safford). The residuary mantle is composed of light gray, yellow and red clays, through which the ore is irregularly distributed. In the Cartersville district the nodules or concretions are largely, partially, or entirely crystalline and usually display the concentric or layered structure to some degree. The Georgia manganese deposits are secondary accumulations concentrated in the residual clays by chemical and physical processes. The ore is mined entirely by open cut, shaft and tunnel work, and on account of its limitation to the residual clays, no heavy or expensive machinery is required. The workings are usually confined to the tops and slopes of the limestone and quartzite ridges, less often to the valley bottoms. The ore is rarely free from some included or admixed quartz and sand, which are often present in sufficient amount to necessitate crushing the ore before washing and jigging. The adhering clay is freed from the ore by washing in a log washer similar to those used in cleansing brown iron ores and ocher.

The manganese deposits are intimately associated with extensive deposits of brown iron ore and some gray specular hematite, and in the Cartersville district, with the deposits of yellow ocher. The proportion of clay to ore is usually larger in case of the manganese than in the closely associated brown iron ores.

Virginia.—The Crimora Manganese Co. continued to exploit the deposit formerly worked by the Carnegie Steel Co., and apparently has successfully adapted the hydraulic process to the peculiar conditions prevailing in the mine. The ore is found in irregular detached masses of variable size scattered through a stiff clay which occupies a basin 0·75×1·5 mile, and 250 ft. in extreme depth. Formerly the ore was extracted by shafts and drifts, a method that was both expensive and wasteful. As subsequently shown, the development frequently

failed to locate masses of ore that were in close proximity to the workings, although they might have been discovered without much difficulty by hand drilling. By the hydraulic process as used there, the top layer of gravel and alluvium is first removed in cars and the clay bank is then washed down under a powerful head of water. The ore being separated from the clay, is shoveled on wheelbarrows and carried to the mill located at the edge of the pit, where it passes through a crusher and washer and is then screened; all material over 0·5 in. in size is passed to a belt sorter and the undersize to jigs.

WORLD'S PRODUCTION OF MANGANESE ORE. (*a*) (IN METRIC TONS.)

Year.	Austria-Hungary.	Belgium.	Bosnia. (*b*)	Brazil. (*e*)	Canada.	Chile. (*d*)	Colombia.	Cuba.	France.	Germany.	Greece.	India.	Italy.
1896	5,941	23,265	6,821	14,120	112	26,152	10,668	(*f*)	31,318	45,062	15,500	57,783	1,890
1897	10,043	28,372	5,344	16,054	14	23,528	8,382	(*f*)	37,212	46,427	11,868	74,862	1,584
1898	14,210	16,440	5,320	26,417	45	20,851	11,176	*Nil.*	31,985	43,354	14,097	61,469	3,002
1899	10,484	12,120	5,270	65,000	279	40,931	10,160	*Nil.*	39,897	61,329	17,600	88,590	4,356
1900	14,550	10,820	7,989	108,244	27	25,715	(*c*)	21,978	28,992	59,204	14,166	132,767	6,014

Year.	Japan.	New Zealand.	Portugal.	Queensland.	Russia.	South Australia (*d*)	Spain.	Sweden.	Turkey	United Kingdom.	United States.
1896..	17,967	66	1,494	305	206,025	*Nil.*	88,265	2,056	.....	1,097	165,135
1897..	17,351	182	1,652	403	270,195	*Nil.*	100,566	2,749	.....	609	161,188
1898..	11,517	290	907	68	229,546	*Nil.*	102,228	2,358	.....	285	190,787
1899..	11,340	137	2,042	747	659,301	102	104,974	2,622	49,468	422	145,548
1900..	15,228	169	1,971	76	(*c*)	*Nil.*	112,897	2,651	*d* 38,100	1,384	231,714

(*a*) From official statistics, except for the United States and Colombia, for which direct reports have been received from the producers. (*b*) Includes Herzegovina. (*c*) Statistics not yet published. (*d*) Export returns. (*e*) Shipments as stated in British Diplomatic and Consular Reports, except for 1899, which are estimated.

THE PRODUCTION OF MANGANESE ORE IN FOREIGN COUNTRIES.

Belgium.—This country produces some manganiferous iron ore, but, strictly speaking, no manganese ore. The output varied from a minimum of 700 tons in 1880, to a maximum of 28,000 tons in 1897, falling to 11,000 tons in 1900.

Brazil.—The production of manganese ore in Brazil began in 1895 and has continued in increasing growth until 1900, in which year the shipments of ore amounted to 127,000 metric tons. During 1901 however the shipments decreased to 96,000 metric tons. In THE MINERAL INDUSTRY, Vol. IX., is an abstract of the comprehensive paper on "Manganese Ore in Brazil," by Mr. H. K. Scott, which appeared in the *Journal of the Iron and Steel Institute,* Vol. I., 1900. This paper has been supplemented by a description of the manganese ore deposits at Queluz, Lafayette district, by Mr. Orville A. Derby, in the *American Journal of Science,* July, 1901, from which the following abstract has been made:

"Queluz District.—In this district, the ore bodies occur in association with granite and gneissic rocks, the calcareous and ferruginous beds that accompany the ore in the other district being completely absent. The mining and prospecting operations thus far effected have been limited to a zone 10 to 20 km. wide on each side of the railroad. In this zone the outcrops of ore are so numerous and large as to indicate an extremely extensive mineralization of an area apparently larger than at present recognized. The existing maps of the region are so defective that no positive correlation of the different outcrops can be made, but there are strong indications of the existence of at least three distinct ore belts."

Although the export duty on manganese ores was reduced to 4% and import duties on mining appliances removed to a great extent, it has been estimated that the product cannot be profitably mined at an exchange of over 12d. per milreis. Several of the smaller mines have suspended operations, although the exports to the United States, United Kingdom and Belgium during the first eight months of 1901 amounted to 34,000 long tons. The shipments during 1900 were 88,127 tons, valued at £151,000, the rate of exchange being taken at 9·5d. to the milreis.

Canada.—The production of manganese ore, principally obtained from New Brunswick and Nova Scotia, has ranged from a yearly minimum of 15 tons to a maximum of 1,789 tons. Since 1897 (with the exception of 1899, when some of the bog or wad manganese ores of New Brunswick were manufactured into spiegeleisen), the total amount mined annually has not reached 100 tons. The establishment of the large steel plant of the Dominion Iron & Steel Co., at Sidney, Cape Breton, will doubtless encourage the development of the Canadian manganese ore deposits. The exports of manganese ore during 1901 amounted to 440 short tons, valued at $4,820.

Chile.—Manganese ores are shipped from the ports of Coquimbo and Carrizal, and occasionally small amounts from Santiago. The mines shipping from the port of Coquimbo are on the plain of Corral Quemasda, about 60 miles distant. The analyses of these ores show Mn, 50 to 51·65%; insoluble, 8·4 to 9·63%; SiO_2, 4·73 to 5·95%; P and Cu, traces; CaO, 4·9 to 8·9%, and moisture, 0·15 to 0·27%. A railroad about 50 miles in length has been built from Carrizal to the manganese mines at the foot of the Ten-Mile mountains, where a number of lodes, averaging from 4 to 5 m. wide are reported. Analyses of 12 samples of ores from this district, indicate Mn, 40·26 to 57·18%; SiO_2, 8·40 to 11·77%, and P, 0·079 to 0·09%. The small quantity of manganese ore exported from Santiago comes from Aculeo, about 32 miles south of Santiago. The yield is about 50% Mn. Manganese ores have also been found at other points, but owing to the lack of railway communication or the poor quality of the ore, the deposits are of no present commercial value.

Colombia.—The manganese ore deposits at present worked are on the Isthmus of Panama, near the Caribbean Sea, about 45 miles N.E. of Aspinwall. The Caribbean Manganese Co., an American concern, is the most important producer in Colombia, and the bulk of ore mined is sent to the United States. In recent years the annual production has ranged from about 8,000 to 10,000 long tons, but in 1901 only 700 tons were shipped.

Cuba.—The mines of the Ponopo Mining & Transportation Co., the Standard Manganese & Mining Co., and the Sierra Maestpa Mining Co. are located in the Province of Santiago de Cuba, about 23 miles from the town of the same name, on the tops or flanks of small hills that branch from the Sierra Maestpa Mountains. The rocks in the neighborhood of the deposits are much decomposed, with the exception of some boulders of porphyry and the jasper which are associated with the ore, and it is asserted that this and the thick vegetation, make it difficult to determine the exact geological formation. At the Ponopo mines it is claimed that manganese may have been derived from one of the igneous rocks, in which it is often present in the form of silicate. This having been chemically decomposed

when the rocks were disintegrated by the action of atmospheric agencies, the manganese was carried in solution to the surface waters, and aided by favorable conditions, was deposited in the form of oxide. As the deposition of the ore was governed by local conditions the extent and continuity of the deposits have to be investigated in each particular case. The ore is found in pockets of greater or less extent, embedded in clay, which has resulted from the decomposition of the original enclosing rock. This clay, in places, assumes various shades of color; red, white and yellow, due to the different stages of oxidation of the iron and manganese contained. The ore is also found associated with red or yellow jasper.

France.—The greater portion of the manganese ore obtained in France is of the carbonate variety from the mines of Las Cabesses (Ariege), which produces annually about 5,000 tons of ore. The tenor of manganese in the ore being increased by calcination from 40 to 45% raw, to 50 to 56% in shipped ore. Smaller amounts are contributed by the mines Romaneche, the Grande Filon (Sâone and Loire), where manganese dioxide is obtained.

Germany.—The greater portion of the home supply is furnished by Prussia, which contributes 98% of the total in the form of manganiferous iron ore, the value ranging from $3 to $7 per ton.

Greece.—The French Government is reported to be carrying on manganese ore mining at Cape Vani, on the northwestern part of the Island of Miños. The ore is claimed to be the dioxide occurring in a basin of Tertiary sediments which are penetrated by trachytic dikes. The ore is mined by open cuts and shafts, and when sorted, contains from 32 to 41% MnO_2. The output ranges from 10,000 to 15,000 tons per year. From 150,000 to 400,000 tons of manganiferous iron ore is annually produced in Greece.

India.—Manganese deposits exist along the East Coast Railway in Vizayanagaram State, Vizagapatam district, and are found in the Chipurupalle taluq of that State. These are chiefly "pockets" close to the surface and reported to be of good quality. Manganese ores are also found in the trap rocks of Belgaum, Dhawar, and Ratnagiri districts, in the Bombay Presidency, and Jhabua, in Central India. An extensive bed of ore, reported to be several miles in extent, exists in Lower Burma. Three localities are specified, viz.: the bank of the Thugo stream, the bank of the Thriabuen, and the great Tenasserim river. The ores are stated to consist of black and gray oxides and wad. The greater portion of ore mined comes from the Madras Presidency, which has shown a constantly increased output from 1,000 tons in 1892 to over 130,000 tons in 1900. Manganese ore is now being mined at Nagpore, and exported from Bombay. This production adds considerably to the quantity exported, which has heretofore come from the mines of Vizagapatam. Indications of manganese deposits have been reported in the Bhandara and Balaghat districts, and explorations are being made.

Italy.—Deposits of both manganese and manganiferous ores occur in Italy, the latter being worked in an intermittent manner, in some instances mining having been interrupted for years. The present annual production of manganese ore is from 4,000 to 5,000 tons, valued at about $5 per ton. The amount of manganiferous iron ore produced has varied greatly, in some years none being mined, while in others nearly 30,000 tons have been mined.

Japan.—Deposits of manganese ore occur in Japan, but it is unlikely that they will ever become a prominent source of supply. A small portion of the product is used in the steel works lately put in operation in that empire, the balance of the ore is exported, amounting in late years to from 6,000 to 9,000 tons, a large decrease from the export of 20,000 tons in 1896, attributable to imperfect preparation.

Java.—Small amounts of manganese ore are produced in the Regencies of Pengasih and Nanggolan. In some years no ore is mined, while in others over 500 tons have been exported.

Russia.—Fully one-half of the world's supply of manganese ore is derived from the Russian Empire, the bulk coming from the Caucasus district, which has been fully described by Mr. Frank Drake in previous volumes of THE MINERAL INDUSTRY. Practically all of the manganese ore known in the market as Caucasian ores comes from Chiaturi, although deposits exist also at other localities, viz.: Kutis, near Chiaturi; near the Choruk river, and in Erivan and Tiflis.

The manganese ore deposits as opened in seven of the hills near Chiaturi, in a brown sandstone of Miocene age, have an average thickness of between 6 and 7 ft. and are free from extreme variations. The deposit has a distinctly stratified structure and is composed largely of pyrolusite, but other manganese oxides also occur. It is quite certain that an area of more than 22 sq. miles of the present surface is underlaid by ore available for mining. With proper sorting no ore from Chiaturi should carry less than 51% Mn. The phosphorus in the ore shipped at present averages about 0·16% and silica not above 8%. The figures given above refer to ore dried at 212°F.

An additional source of supply is the Nicopol district, the initial shipments being made in 1897. The average analyses showed: Mn 46%, SiO_2 12·5%, and P 0·25%. Messrs. Leech, Harrison and Forwood, of London, give the average analyses of Chiaturi ore, when dried at 212°F. as: Mn 51%, P 0·15%, SiO_2 7·5 to 8·5%, and Fe 1%. The manganese ores of the Nicopol district are described in detail in the special article by Mr. Frank Drake, given later in the following pages of this section.

The mines are usually owned by natives, who hold parcels of ground varying in size from 0·5 acre to 50 acres. Some of the proprietors mine the ore from their own land while others lease the mining right and receive a royalty therefor. The railroad from the mines to the harbor is owned by the Government, which makes exorbitant charges for shipment from Chiaturi to Sharopon, a distance of about 25 miles. The exports of manganese ore from Batoum and Poti during 1900 were 373,202 and 52,917 long tons, respectively, which was a considerable decrease from the exports during 1899.

Spain.—The greater portion of the manganese ores produced in Spain is of the carbonate and silicate varieties, from the Province of Huelva. Mr. Carlos Sundheim states that one-half of the output is silicate, averaging 33% Mn and from 30 to 37% SiO_2. The shipped ore is classified as yielding from 40 to 47% Mn, with 16% SiO_2; from 36 to 39% Mn, with 16% SiO_2; 34% Mn, with 16% SiO_2, and 30% Mn, with no guarantee as to silica. The ore is exported principally to Belgium and Luxemberg, where it is stated to be mixed with the

aluminous minette ores of Luxemberg for smelting. A small amount of manganese oxide, usually from 200 to 300 tons, is obtained from the provinces of Oviedo and Teruel, but these localities will not be important producers until railroads are built to the mines. The total production of manganese ore in Spain ranged from about 400 tons in 1894, to 136,500 tons in 1899, falling to about 113,000 long tons in 1901. The exports of manganese ore during 1901, as reported by the *Revista Minera,* were 91,672 metric tons, as compared with 129,916 metric tons in 1900.

Sweden.—Sweden has been a constant producer of small amounts of manganese ore, all of which comes from Wermlands and Jonkopings. In recent years from 2,000 to 2,700 tons have been mined, but in 1890 the total production amounted to more than 10,000 tons.

The Nicopol Manganese District in Southern Russia.

By Frank Drake.

Nicopol is a town in the Government of Ekaterinoslav, on the river Dneiper, about 190 miles above Odessa. Being the point from which shipments of ore

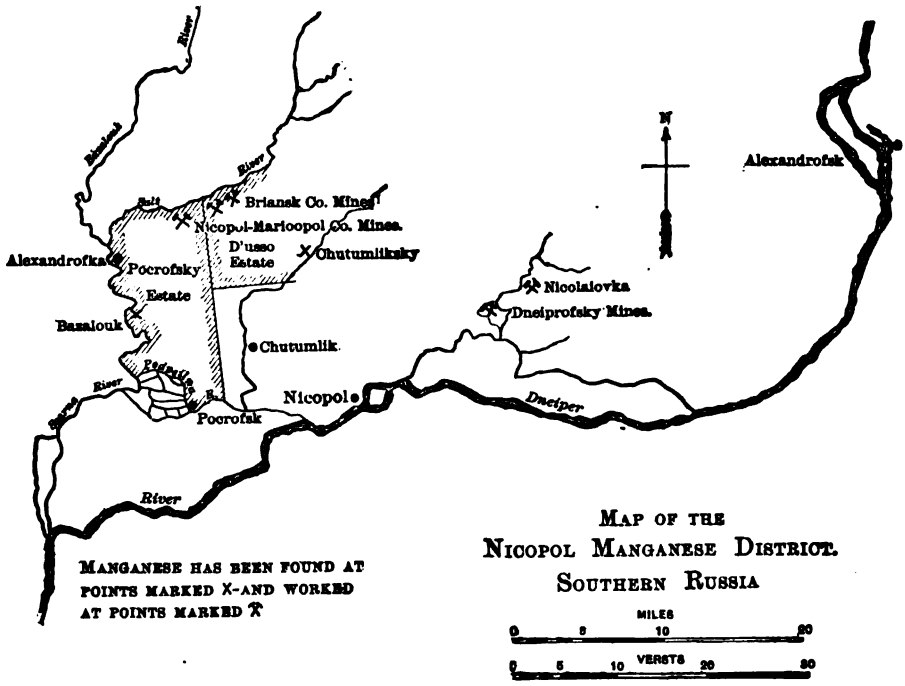

Fig 1.

take their departure for the outer world, Nicopol has given its name to the neighboring manganese district as well as to the ore, although the deposits lie at a considerable distance from the town.

The accompanying map, Fig. 1, shows the region surrounding Nicopol, with the localities at which manganese ore has been mined or discovered, and indicates in a general way, the location and extent of the district.

The first discovery of ore was made on the Pocroffsky estate of the Grand Duke Michael Nicholovitch, in 1885, or previously. Preliminary explorations were made in that year, and mining commenced in 1886, the workings then opened becoming known as the Pocroffsky mines. At present the following mines are in operation:-

1. The Pocroffsky mines, comprising part of the Pocroffsky estate, and also including territory leased from the neighboring D'Usso estate; operated by the Nicopol-Marioopol Mining & Metallurgical Co. Up to the end of 1891 these were the only mines in the district, the others mentioned below having since been gradually opened.

2. The Llwoff mines, on the D'Usso estate; operated by the engineer Llwoff.

3. The Briansk mines, on the D'Usso estate; operated by the Briansk Co.

4. The Gorodistcheffsky mines (also called Dneiprofsky mines), 30 versts southeast from the three above mentioned; operated by the Dneiprofsky Co.

5. The mines of the Pyrolusite Co.

Of these mines the first three are grouped along a small stream, known as Salt river (so called on account of the taste of its waters), while the others are near the village of Nicolaiovka, about 20 miles southeast from this locality.

The mines near Salt river are leased by their operators at royalties equivalent usually, to from 60 to 90c. per ton of ore shipped.

So far as is known, the Pocroffsky mines only, have exported ore; a considerable proportion of their total product, however, is used at the steel works at Marioopol, on the sea of Azov, or sold to Russian consumers. The Briansk Co. and the Dneiprofsky Co. use their entire product at their steel works, near Ekaterinoslav, while the product of the Llwoff mines is taken by the Briansk Co. Thus, nearly the whole product of the Nicopol district is used in Russia.

The production of the district (in long tons) has been as follows:—

1886	4,033 tons.	1891	16,666 tons.	1896	44,884 tons.
1887	3,651 tons.	1892	28,961 tons.	1897	55,966 tons.
1888	5,508 tons.	1893	(a) 76,450 tons.	1898	58,717 tons.
1889	8,517 tons.	1894	(a) 57,463 tons.	1899	95,400 tons.
1890	10,645 tons.	1895	36,881 tons.	1900	87,223 tons.

(a) Partly unassorted ore.

In 1901 the yield is said to have fallen off considerably, owing to the failure of a number of metallurgical enterprises in the south of Russia.

Topography.—The Nicopol district is part of the great steppe region of southern Russia, and its topography is of a prairie-like character with gentle undulations and an occasional marked eminence or depression. Except in some cases along permanent water courses, it is entirely treeless. It is an agricultural rather than a mining country and a large proportion of the land is utilized for farming purposes.

The Ore Deposit.[1]—In the district south of the Salt river, the manganese ore is found in a horizontally bedded deposit, usually about 3·5 ft. thick; in a few places the thickness shrinks to about 1 ft., while in others it increases to 6 ft.

[1] My personal familiarity with the Nicopol district is confined to the mines near Salt river, particularly the Pocroffsky mines, so that statements regarding the ore deposit and methods of working apply to the Pocroffsky and neighboring mines, rather than to the mines near Nicolaiovka. Access to the latter was denied me as well as information concerning them, and statements regarding their working are merely those current in the neighborhood.

The bed lies between strata of clay of similar appearance but of different geological ages, the overlying clay being of Miocene age, while the ore deposit itself and the underlying clay are Oligocene. The deposit consists mainly of a somewhat impure pyrolusite, intermixed to a greater or less extent with sandy, calcareous and argillaceous material, the proportion of the foreign matter varying considerably in different parts of the bed. The ore deposit is almost entirely lacking in the distinctly stratified structure that characterizes the similar manganese deposit of Chiaturi, in the Caucasus. The Nicopol ore occurs in massive form, and in some places is quite hard, while in others it is very soft. The harder parts are usually more or less porous and honeycombed, the cavities being generally filled entirely or partly with sandy or clayey matter. The texture of even the harder parts of the deposit permits the ore to be mined entirely by a pick without the use of explosives.

The workings near Nicolaiovka are said to be in a deposit having similar characteristics to the deposit at Salt river, and as manganese ore has been found at Chutumliksky, between Nicolaiovka and Salt river, it is possible that the workings are on the same bed. It may also be worth mentioning that a horizontal bed of manganese ore occurs near Krevoi-Rog, a village about 40 miles northwest from the Pocroffsky mines, and in line with them and Nicolaiovka. It would perhaps be an unwarrantable suggestion that the ore bed worked at Salt river is identical with that at Krevoi-Rog, but the facts as they exist are at least suggestive of very extensive manganese deposits in this part of Russia. The ores of this region are high in phosphorus and, in some localities, comparatively low in manganese, but as variations in the latter are characteristic of these, as well as of the Caucasian manganese deposits, it may be possible that there are localities within the manganese-bearing area containing ores of a grade desirable for metallurgical purposes.

Chemical and Physical Characteristics of the Ore.—The chemical characteristics of the crude ore in the vicinity of Salt river are indicated by the following partial analyses:—

	Moisture.	Silica.	Metallic Manganese.	Phosphorus.
Sample 1.....	5·40	27·60	30·60	0·24
Sample 2.....	5·70	27·00	29·58	0·28
Sample 3.....	3·05	27·70	34·63	0·25

At Nicolaiovka the crude ore is said to carry about 30% Mn.

The grade of the shipping ore produced at the Salt river mines by separating the gangue from the crude ore by hand picking, is shown by the following analyses of samples representing two large shipments from Pocroffsky mines: Sample 1: Moisture, 8·05%; MnO_2, 66·78% (42·21% Mn); SiO_2, 13·95%; Fe_2O_3, 2·49%; Al_2O_3, 2·95%; MgO, 2·38%; P_2O_5, 0·42%; C, 1·64%; SO_3, 0·95%; total, 99·61%. Sample 2: Moisture, 3·40%; MnO_2, 73·89% (46·71% Mn); SiO_2, 13·62%; Fe_2O_3, 2·68%; Al_2O_3, 2·33%; MgO, 2·17%; P_2O_5, 0·45%; C, 1·41%; SO_3, 0·91%; total, 100·86%. At the Dneiprofsky mines the washed crude ore yields two grades of shipping product, one containing about 50% Mn, and the other about 40% Mn.

The physical characteristics of the Nicopol ore are favorable to its commercial value, as it contains a fair proportion of lumps, usually of a porous nature; while, for the most part, both the lumps and the smaller pieces are at least moderately hard, so that comparatively little fines are produced by handling.

Labor and Wages.—The mines in the Nicopol district are dependent for labor to operate them, largely on the neighboring peasantry, reinforced to a greater or less extent by the migratory bands of peasants which form so striking a feature of Russian peasant-life. The underground laborers are the most stable, and, while coming originally from the local peasantry, they have abandoned agricultural labor and form a fairly permanent, though limited, mining population. The labor employed in screening and sorting the ore and for general surface work, however, is composed almost entirely of migratory bands, and is not only uncertain as regards supply but also of an unstable character. This class of labor is composed of peasants who, on account of insufficiency of employment, have left their native villages for parts of the country where work is obtainable. Among them is a considerable proportion of women, who are largely employed at the mines for sorting ore.

Agriculture being the dominant industry of this region, its requirements and convenience have molded custom in matters pertaining to labor employment. Thus there has arisen a practice of employing labor an entire season (summer or winter) for a lump sum, and from this has resulted the custom of the migratory peasants of leaving their employment and returning to their villages for a longer or shorter time at the end of each season's work. Through the practice of generations, this custom has become so fixed that it is difficult to persuade the peasants to forego these visits to their homes, consequently the mine operators are compelled to submit to the inconvenience of having practically their entire force of ore-sorters desert for a more or less uncertain period each year.

There is a large demand from the mine operators for men, horses and wagons to transport the ore from the mines to the Dneiper, and this work is performed by the local peasantry in seasons when there is no agricultural work. The supply of labor for transportation is thus uncertain and quite as unsatisfactory as that for sorting of the ore. The wages earned by miners in the Nicopol district are from 60 to 65c. per day, lodging, fuel and water being furnished in addition. Mechanics receive about the same wages as miners, except when employed by the season, or by the year, in which case their wages are lower. For ore sorters working by the day, wages are from 30 to 50c. per day for men, and from 25 to 35c. for women, lodging, fuel and water being furnished as in the case of the miners. Men employed by the season for sorting ore, and for general labor, receive about 32c. per day for the summer season, and about 15c. for the winter season, while women employed by the season receive about 20c. per day for the summer and about 12c. for the winter. All laborers employed by the season, however, receive in addition lodging, food, fuel and water, which, excepting lodging, costs the employers about 8c. per day for each person. The wages of peasants engaged in transporting the ore are from 70c. to $1·25 per day, for a man, a wagon and two horses. All regularly employed laborers receive free medi-

cal attendance, and in some cases a hospital, school and church are maintained by the mine operators.

The hours of labor for miners and underground laborers are 10 per day, but conforming to the custom of the agricultural laborers of the region all surface laborers, excepting a few whose work obliges them to conform to the hours of the miners, work from sunrise to sunset, summer and winter, with intermissions of one hour for breakfast, one hour at noon, and one-half hour about 3 or 4 o'clock in the afternoon, for tea. The average number of working hours per day for surface laborers under these conditions, is about 9·5. Owing to the large number of holidays the number of working-days per year is but 277.

In 1900, 1,325 laborers were employed in and about the mines of the Nicopol district, exclusive of the peasants engaged in transporting the ore. These latter at times number 800 or 1,000.

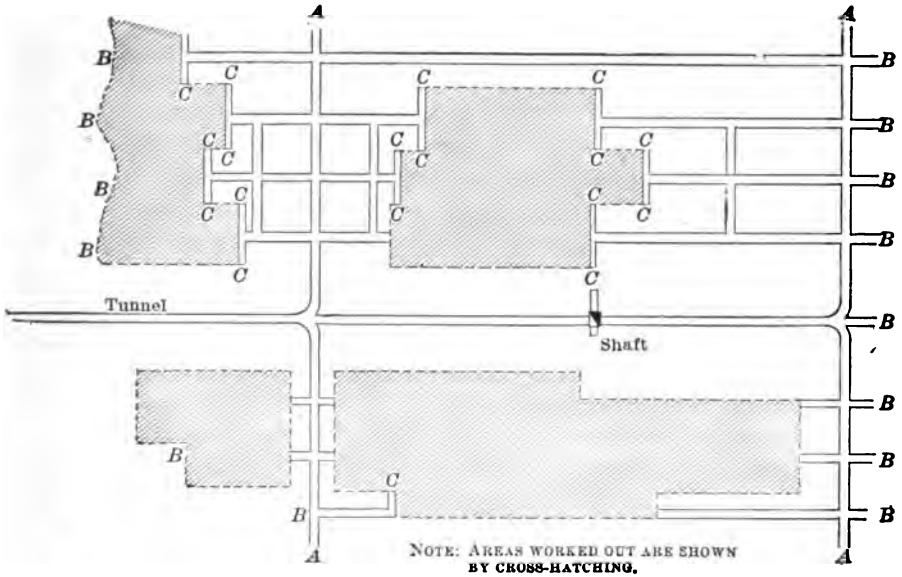

FIG. 2.—PLAN OF THE WORKINGS OF THE SOFIA MINE.

Mining.—The mines near Salt river are opened mostly by tunnels or adits extending into the gently sloping hillside that forms the southern slope of the shallow river-valley, but in one or two instances the workings are reached by vertical shafts at points some distance up the slope of the hill, from the outcrop of the bed. The practice is to open the deposits by main and secondary gangways, which extend at right angles to each other, and thus subdivide the bed into rectangular blocks, as shown in Fig. 2, *AA* representing the main gangways, and *BB* the secondary gangways. The main gangways are wide enough for double tracks and are of sufficient height to permit the passage of horses. The secondary gangways accommodate a single track and are high enough only for hand tramming. As the overlying clay will not stand unsupported for any considerable time, the gangways are closely timbered as driven. As a rule, however, it is necessary to lag only the backs, leaving the sides open.

Stopes are opened from the secondary gangways, and the ore trammed by hand to the main gangways, thence it is taken by horses to the shaft or tunnel-mouth. The main gangways should be placed a proper distance apart in order to avoid excessive cost for hand-tramming, but in most instances that have come under my observation, they are spaced too far apart for the best results. The secondary gangways are commonly spaced about 70 ft. between centers, leaving the shortest dimension of the blocks into which the bed is subdivided, about 64 ft. As the surface of the clay underlying the ore deposit is substantially a horizontal plane, the floors of the openings are kept at this level, and when the required height of an opening is greater than the thickness of the ore bed, the overlying clay is removed.

The ore body having been opened in this manner, stoping is commenced in the blocks most remote from the shaft or main tunnel. The work of stoping consists in driving short drifts into the blocks, from the secondary gangways. These drifts are opened in pairs from any secondary gangway, as at *CC*, Fig. 2, one drift being opened in the block on the right-hand side of the gangway, and the other directly opposite, in the block on the left-hand side. The stoping drifts are about 32 ft. long, and extend halfway through the block, where they meet similar drifts driven from the secondary gangway bounding the opposite side of the block. The native practice was to make the stoping drifts about 5·25 ft. wide, but by increasing them, wherever the ground permitted, to a width of 7 ft. the product of ore per man per day was largely increased. The height of the stoping drifts is equal to the thickness of the ore bed, none of either the overlying or the underlying clay being removed. The stoping drifts are closely timbered and the backs lagged. A pair of stopes having been opened near the center of two adjacent blocks, and the ore removed, the timber is pulled out, which allows the overlying clay to fall in and fill the opening. This usually occurs immediately upon removal of the timber, but in some instances the clay is so firm that it stands for a short time unsupported. In this operation of filling the stopes, as much of the timber as possible is saved for subsequent use, as, the region being remote from sources of timber supply, its cost is the largest single item in the expense of mining. The saving of timber was encouraged by the payment of premiums, and from 60 to 70% of the timber employed in the stopes was regained. A pair of stopes having been opened and filled, another pair is opened directly adjacent, and the operation repeated, until the whole bed is removed over the area embraced by the opening work. Stoping is done by parties consisting of two men, one mining the ore and the other tramming it to the main gangway. They are paid by the car, and as miner and trammer exchange places from time to time, each shares equally in the proceeds of the work. Timber is supplied them, but they are required to put it in place. Lights (candles) and other supplies are charged to them and deducted from their gross earnings, which include in addition to the rate per car, the premiums on timber saved. All implements are furnished by the operators. The ore is trammed underground in small cars running on steel rails, holding about 15 cu. ft., or slightly over half a ton of ore. They are filled in the stopes and go without rehandling to the dump.

The mines at Salt river are at a slight elevation above the river, and are almost

perfectly dry, except after prolonged seasons of heavy rain, when some inconvenience from water is occasionally experienced.

The ore is mined with a pick, and under the methods described, the average daily production of each miner is about 10 tons. The average daily quantity handled by the trammers is of course equal to that produced by the miners. Considering the very favorable conditions for mining, the results obtained by the miners seem small in comparison with those that would probably be reached under similar conditions in the United States, and by the same standard of comparison, the work accomplished by the trammers appears even more unfavorably; but as the day's wage of the miners is less than one-third and that of the trammers but little over one-third of that paid similar labor in this country, the labor costs per ton, especially that for mining, are not high.

Reference has already been made to the scarcity of timber in this region. The principal source of supply is the Government of Smolensk, from whence the timber is floated down the Dneiper to various points in the steppe region. The timber obtainable for mining purposes looks exceedingly small to one accustomed to American practice, the diameter of the largest logs not exceeding 8 in. On account of the small size of the timber, and the character of the clay overlying the ore deposit, it is necessary to place the sets much closer together than is commonly done in mining practice, the usual distance being 2·3 ft. between centers. As a rule no lagging is used on the sides of drifts or other openings, but slabs are used for the backs.

Ore Dressing.—At the Dneiprofsky mines the crude ore is sized by trommels, and subsequently jigged; the products have already been referred to. At the mines near Salt river, however, hand-screening and sorting alone are used for the beneficiation of the crude ore. The process at the Pocroffsky mines is as follows:—

1. The crude ore is screened, separating it into two classes.

(*A*) That above 0·5 in. in diameter.

(*B*) That below 0·5 in. in diameter.

2. Class *A* is then cleaned as described below, and hand-picked, yielding a product locally called "large" ore, which amounts to about 12% of the weight of the crude ore extracted from the mines. It contains about 47 to 48% Mn on sample dried at 100°C.

3. Class *B* is screened, yielding two classes.

(*C*) That above 0·16 in. in diameter.

(*D*) That below 0·16 in. in diameter.

4. Class *C* is hand-sorted, which separates the pieces of clay and other waste material. The shipping-ore obtained is locally known as "small" ore. It is about equal in quantity to the large ore, amounting to about 12% of the crude ore. It contains about 41 to 42% Mn on sample dried at 100°C.

5. Class *D*, amounting to from 66 to 75% of the crude ore taken from the mines, and containing about one-half of all the metallic manganese carried by it, forms the tailings, which go to waste. This class contains about 27% Mn on sample dried at 100°C.

In making shipments the large and small ores are mixed in proportions to satisfy the conditions of sale.

For the first screening of the crude ore the screen consists of a box-like frame, with a bottom of wire cloth of suitable mesh, and two handles projecting at each end. A quantity of ore having been shoveled onto the screen, it is taken in hand and shaken by two men. When the operation is complete the lump ore remaining on the screen is dumped upon a rough board table and the adhering clay and other foreign material removed by small hammers or pieces of iron, the waste material being sorted from the clean ore. The cleaning and sorting are usually performed by women, who are more efficient at it than men.

In the second screening process, which treats the material passing through the large screens, a circular screen is employed which consists of a thin board, bent to a circular form, with a piece of wire cloth of proper mesh stretched over it. It is suspended by ropes attached to the wooden frame, from a tripod formed of wooden poles. The ore is shoveled onto this screen, and by a rapid gyratory motion, the separation of the fine waste ore is quickly accomplished. The foreign material is then picked from the ore remaining on the screen, which serves as a picking table. This second screening process and the subsequent hand-picking are largely performed by women. Ore cleaning and sorting are mostly done by small contractors, who take the work at a fixed rate per pood (36 lb.) of sorted ore, and hire their own labor by the day, month or season. It would seem certain that some mechanical washing process would give more efficient results than the present crude system of hand sorting. Experiments in this direction, with large lots of the ore, have, indeed, been made in England and Germany, and have indicated that the cost of treatment would be less and the yield of marketable ore would be greater than by the present process, owing to the saving of a large proportion of the fine ore that now goes to waste. On the other hand the percentage of moisture in the washed product is considerably greater than in the hand sorted ore. Studies of this latter point and of questions of water supply have, up to this time, deferred the installation of a washing plant.

Transportation.—Practically all the ore produced in the Nicopol district is transported by wagon to the Dneiper, where it is loaded on barges for shipment. In the case of the Dneiprofsky mines, the distance of wagon transportation is comparatively small. The ore of the mines near Salt river, however, is transported either to Nicopol itself, distant about 17 miles, or to Pocroffsk, a neighboring village, about 12 miles distant. This transportation is performed by the peasants of the surrounding country, who, with their wagons and horses, are hired for the purpose by the mine operators at a fixed rate per pood of ore carried. In addition to the transportation, this price includes a rough screening, loading and unloading. In loading the wagons, the ore is taken from the piles into which it has been placed by the ore-sorters and first thrown with shovels against a screen, one end of which rests on the ground, and the other upon a prop, to hold the screen in a steeply inclined position. The fine particles of ore, which contain more foreign matter than the coarser pieces, are thus separated, and the coarser part is then shoveled into boxes holding from 200 to 250 lb., and transferred to the wagons, which carry a load of about one ton. At the river the ore is discharged

from the wagons onto a stock-pile, the wagons driving on top of the latter, and unloading by shoveling, or by upsetting the wagon-box, or sometimes the entire wagon.

The average price paid for transportation from Salt river to Nicopol is about 87c. per ton, while from Salt river to Pocroffsk the rate averages about 75c. per ton.

The disadvantages of this means of transportation are severely felt by the mine operators; its inherent expensiveness, the fluctuating and uncertain supply of wagons, the changes of weather with the consequent bad condition of the roads, all militate against the prosecution of the industry. It seems probable, however, that improved facilities for transportation to the Dneiper will be available in the near future, as a railroad was commenced in 1901, and will, it is expected, be completed in 1903. The route crosses the Dneiprofsky mines and passes the Pocroffsky mines at a distance of 10 versts (6·7 miles). A branch will extend to Nicopol, and a branch connection with the Pocroffsky mines is contemplated.

For further shipment the ore is rough screened and transferred from the storage places at the Dneiper to barges having a capacity of about 350 tons. The ore is transferred on stretchers, each consisting of a rectangular wooden frame, the two longest sides projecting so as to provide two handles at each end, a piece of canvas being stretched across between the two short sides of the frame, for the reception of the ore. Two men carry a load of about 180 lb. The cost of loading barges in this manner is about 8c. per ton, screening included.

If the destination of the ore is one of the steel works in southern Russia, it is usually taken from Nicopol or Pocroffsk, up the Dneiper to Alexandrovsk, and transferred to the railroad. If it is for foreign shipment, it is taken down the river to Nicolaieff, where it is transferred to ocean-going vessels.

In conclusion I desire to express my obligations to the directors of the Nicopol-Marioopol Mining & Metallurgical Co., of St. Petersburg, for permission to use information gathered while in its employ, as well as for facts communicated especially for the present paper. Information has also been kindly given by Mr. Thomas E. Heenan, United States Consul at Odessa.

MICA.

THE total production of sheet mica during 1901 was 360,060 lb., valued at $98,859, a considerable decrease from the quantity produced in 1900. The total production of scrap mica during the year is estimated at 2,165 short tons, valued at $19,719. North Carolina registered an increased production in sheet mica, but the scrap mica produced was considerably less than the production of 1900. The imports of both sheet and scrap mica increased correspondingly to the decreased domestic production, for mica may be imported from Canada and India, especially the latter country, at much lower prices than it can be obtained in the United States. The consumption of sheet mica in stoves, and of the smaller discs and irregular shaped pieces for insulation and electrical purposes has increased during the year, keeping pace with the increased production of machinery and fittings. A new use for mica scales or finely ground mica, according to U. S. Patent No. 667,488 of February 5, 1901, issued to G. H. Brabrook, of Taunton, Mass., is to combine one part of mica mixed to a thin paste with water and add about three parts of plaster of Paris. After thorough incorporation the mixture is cast on the pattern of the mold desired, dried at from 250° to 300°F. for from 10 to 12 hours, until the molds are apparently dry, when the temperature of the ovens is raised to about 1,000°F. for from 2 to 3 hours. The molds are then allowed to cool slowly. When cool molds of this kind may be used for casting metals of any kind, and are particularly adapted for small sharp castings, and also castings of considerable surface but thin and light body. Messrs. Reed & Barton, of Taunton, Mass., have obtained control of the patent.

United States Patents Nos. 686,929 and 686,930, of November 19, 1901, were issued to R. W. Heard and R. A. L. Snyder, of Pittsburg, Pa., assignors to the Mica Machine Co., of Pittsburg, Pa., for a method of and machine for the preliminary releasing or lessening of the bonds or force naturally uniting the adjacent sheets or laminæ of mica. The material, after preliminary treatment, is made to adhere to a prepared surface by suitable binding material, the flakes evenly distributed, and the non-adhering ones brushed off, when the artificially formed sheet or film is ready for use.

PRODUCTION OF MICA IN THE UNITED STATES.

State.	1900.				1901.			
	Sheet.		Scrap.		Sheet.		Scrap.	
	Pounds	Value.	Short Tons.	Value.	Pounds	Value.	Short Tons.	Value.
New Hampshire	25,241	$11,358	2,405	$21,645	65,800	.....	250	.....
North Carolina and Virginia	34,500	24,150	2,790	19,530	266,160	.....	1,775	.....
South Dakota	65,000	45,000	222	1,554	25,000	.....	.....	.....
Other States	2,500	2,000	20	160	3,100	.....	146	.....
Totals	127,241	$82,508	5,417	$42,889	360,060	$98,859	2,171	$19,719
						(a)		(a)

(a) Not given.

California.—Late in 1901 a deposit of mica of the muscovite variety, with a mica schist hanging wall and granite foot wall, was discovered in the Piru mining district, Ventura County. The mica intrudes through feldspar, and consists of both mass and book mica. Active development of the deposit is promised during 1902.

Idaho.—The mica deposits situated in the Robinson mining district, Latah County, about 18 miles from the Northern Pacific Railway, are operated through a 600 ft. cross cut, and 500 ft. upraise, enabling the recovery of the mica at about $5 per ton for mining. The output during 1901 was slightly greater than that of 1900.

North Carolina.—The output of sheet mica increased considerably during 1901, but this increase was offset by a decreased output of scrap mica. The J. E. Burleson Mica Co. was organized during the year to mine and manufacture mica at Marion.

South Dakota.—The Black Hills Porcelain Clay & Marble Co. made small shipments of mica from Custer County during the latter part of 1901, and early in 1902 made two 150-ton shipments. The Crown mica mine owned by the Chicago Mica Co., made regular shipments of from two to four carloads per month, to the company's plant at Valparaiso, Ind. The Daly mine, owned by the same company, is said to yield the largest books of mica of any company in Custer County. Early in 1902 articles of incorporation of the National Mica Co., capitalized at $1,000,000, were filed. The company will work mines in Custer County.

Canada.—The Mica Boiler Covering Co., Ltd., of Toronto, with factories in Montreal and London, England, is the principal home consumer of Canadian mica. The factory at Montreal employs about 50 workers and consumes daily one ton of crude mica. The mica is cleansed by machinery of special design, and is then made into the required products in other sets of machinery. The mica mines of Quebec produce annually large quantities of white and amber sheet mica, besides a considerable quantity of the small flakes used in electrical insulating material. The mica mine at Perkins Mills, Quebec, owned by Messrs. Blackburn Bros., of Ottawa, is the largest producer in Canada. Its output during 1900 amounted to over 200,000 lb. of thumb trimmed mica, while that of 1901 was slightly larger. The shipments from Quebec during 1900 were, in detail: 338,200 lb. of 1-3 in. mica, valued at $31,860; 92,359 lb. of 2-3 in., valued at $18,534; 71,332 lb. of 2-4 in., valued at $24,953; 25,637 lb. of 3-5 in., valued at $15,706; 11,762 lb. of 4-6 in., valued at $11,451; 1,995 lb.of 5-8 in., valued

at $2,696; total, 541,285 lb., valued at $105,200. Besides the above there were still in hand 64·5 short tons of thumb trimmed mica, valued at $33,400, forming a total product of 335 short tons for 1900, valued at $138,600, not including stocks of raw mica at the mines. The total production of mica for Canada for 1901 was valued at $160,000, against a value of product during 1901 amounting to $166,000.

India.—The Madras Board of Revenue, early in 1902, amended the rules for mica mining in the Nellore district to conform to the general mining rules of the Government of India. This action was made necessary by the fact that speculators had located and obtained mining leases which they had no intention of working, and held for merely speculative purposes to the restriction of the genuine operations of the district. Applications for mining leases must now be accompanied by a deposit of 500 rupees, or such sums as the discretion of the Government may determine.

The Mica Industry of New Hampshire.

By Albert J. Hoskins.

There are at the present time in this State about 300 abandoned properties, 50% of which should pay a fair percentage on money invested, if they were legitimately operated. Yet companies owning these properties cannot give a good title on account of litigation or obstructive agreements entered into by their stockholders.

The two companies situated in Groton, the Palermo and the Valencia mica mines, both of which were operated several years ago, were operated legitimately for a number of years, and the immense output obtained yielded handsome profits, also the old Ruggles mine, of Grafton, and the Alstead, of Cheshire County, were dividend payers, when the work was honestly carried on. But even these properties which were once so valuable and have produced mica output valued at over $1,000,000, are so tied up with litigation and stock-jobbing corporations that it is impossible to get a title that would warrant the investment of capital.

There are still several good prospects in this State that would undoubtedly bring good returns if properly managed, and if not incorporated under fictitious values. New Hampshire, according to statistics, has furnished more mica than any other State in the Union, having furnished at one time 80% of the annual production of the United States. Its mica has always had the preference in the open market for excellence in quality. The present discouraging conditions undoubtedly will shortly be overcome and New Hampshire will again rank as the leading producer in the United States.

The Union Mica Co., of New York City, owns the only plant operated in Groton during 1901, which is wholly engaged in the manufacture of mica specialties used in connection with electrical insulation. The product is known as compressed mica or mica-board, and is made from refuse mica. The process of manufacture is a simple one. The mica is first split up into very thin slices and built up in a form to the desired thickness, shellac being used between each piece

in the form of cement. It is then subjected to a pressure of 2,000 lb. to the sq. in., and pressed to a definite thickness. It is next steamed and placed in a mold to procure the required shape, and completed by placing in a kiln and hardening.

A large number of molds and forms are necessary for the making of various shapes required by the trade. The amount of crude mica necessary for the manufacture of mica-board specialties is very small, one ton of waste mica will sometimes make finished material valued at $1,000, labor being the greatest item.

Of the two mines in operation during 1901 and 1902 in Alstead, the Davis mine, which is the property of the Davis Mica Co., of Keene, employs about 10 men, and averages to produce one ton per day, which is customarily sold in the rough. The mica after being blasted out undergoes a hand dressing (rifting), in which operation the refuse or cracked and stained mica is split off. The remaining clear and free splitting mica is trimmed and assorted to four grades or sizes. No. 1 grade measures either 4×6 in. or 6×8 in., and sometimes larger. No. 2 grade averages from 3×4 in. to 4×6 in. No. 3 grade averages from 2×4 in. to 3×4 in. No. 4 grade averages from 1 in. to 2×4 in. Mica of No. 4 grade is known and sold as rough trimmed mica. The waste or trimmings are sold to the mills for grinding purposes at from $15 to $20 per ton.

The old Bowers mine, owned by Henri Picard & Co., of New York City, is operated on a larger scale than the Davis mine. About 25 men are employed in the mines and mills, the average output of the mines being two tons per day. Eighty per cent of this product is ground at the mills into grades ranging from 10 to 200 mesh to the inch. The grade most in demand is No. 40, which is used extensively in the manufacture of electrical insulating buttons, over 300 tons per annum being absorbed for this purpose. Owing to the changes of style in wall papers during the past two seasons, the demand for mica ground to 160 to 200 mesh to the inch is declining. The demand for the coarser grades meanwhile is increasing steadily. The prices in June, 1902, for ground mica ranged from $40 to $100 per short ton, f. o. b. mills.

MOLYBDENUM.

THE production of molybdenum and ferromolybdenum in the United States during 1901 amounted to 35,000 lb. and 16,000 lb., respectively. The price for molybdenum metal ranged from $1·55 to $2 per lb.

The production of molybdenite in the United States during 1901 amounted to but 10 or 15 long tons which, however, furnished but a very small proportion of the domestic consumption of the metal. The value of the production varied from 10c. to $1·10 per lb., and to be marketable the ore must contain over 45% Mo and must be free from copper. The average price of an ore containing from 50 to 55% Mo is about $400 per ton. The demand for the metal molybdenum has been largely increased in recent years due to the property possessed by the metal to render chrome steel self-hardening. It is claimed that the self-hardening property can be imparted to chrome steel by the addition of one-half the quantity of molybdenum, as compared with tungsten.

L. F. Kollock and Edgar F. Smith[1] precipitate molybdenum electrolytically from solutions acidified with H_2SO_4 or $HC_2H_3O_2$ as a black, adherent coating of hydrated molybdenum sesquioxide which is dissolved in HNO_3, ignited and weighed as molybdic acid. Analyses of molybdenite may be hastened by applying this method to the aqueous solution of the fusion with Na_2CO_3 and $NaNO_3$, with the precaution to use $HC_2H_3O_2$ if sulphur is to be determined.

The volumetric determination of molybdenum steel is described by F. T. Kopp.[2] Dissolve 0·5 g. of the sample in a large platinum crucible with 2 c.c. of H_2SO_4 (sp. gr. 1·58) and 12 c.c. of water, evaporate and add 30 g. of fused $KHSO_4$, fuse carefully, cool and dissolve in 500 c.c. of hot water; digest at boiling point until solution is clear, add 100 c.c. of ammonia and make liquid up to a liter. After mixing remove precipitate by passing through a dry filter; take 500 c.c. of the filtrate, add 40 c.c. of H_2SO_4 and reduce the solution by passing through a column of zinc (Jones reductor). Add 10 c.c. H_2SO_4, filter and titrate the reduced molybdenum in the solution with permanganate. A blank test is made with a solution containing 450 c.c. water, 50 c.c. ammonia and 40 c.c. of H_2SO_4 as a check for the errors caused by the impurities in the zinc. A similar process is used for ferromolybdenum with the exception that at first 0·5 g. of the sample is dissolved in 15 c.c. of strong HNO_3 before evaporating with H_2SO_4 without the addition of water.

Molybdenum alloys are produced in the electric furnace by the reduction of molybdenum oxide with oxides of other metals as described under the caption "Tungsten," elsewhere in this volume.

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[1] *Journal of the American Chemical Society*, August, 1901, pp. 669-671.
[2] *Ibid.*, February, 1902, pp. 186-188.

MONAZITE.

THE production of monazite in the United States during 1901 amounted to 748,736 lb., valued at $59,262, as compared with 908,000 lb., valued at $50,680 in 1900. While the output of 1901 is less than that of the previous year it is of greater value, due in part to the better quality of product, which was more highly concentrated, and in part to the increased price. It is quite probable that the thoria content of the output of 1901 equalled the larger output of 1900. The greater part of the output of 1901 was obtained from Burke and Cleveland counties, N. C., although small quantities were also obtained from McDowell and Rutherford counties, N. C., and from South Carolina. Early in 1902 a tract of 353 acres of monazite land near Ellenboro, Cleveland County, N. C., is reported to have been purchased for a number of German manufacturers. The prospect for an increased production of monazite during 1902 is very promising. The demand for Carolina monazite has increased on account of the increased price of the Brazilian product resulting from the recent control by one concern of practically all the monazite properties in Brazil.

PRODUCTION OF MONAZITE IN THE UNITED STATES.

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	Pounds.			Pounds.	
1893	180,000	$7,600	1898	150,000	$7,500
1894	750,000	45,000	1899	330,000	18,480
1895	1,900,000	114,000	1900	908,000	48,805
1896	17,500	875	1901	748,736	59,262
1897	40,000	2,000			

The following is a recent analysis of monazite from New Granada which has been reported by Nicholas J. Bluman: Ce_2O_3 25·02%, La_2O_3 22·41%, ThO_2 18·00%, MnO 1·21%, CaO 2·13%, SnO_2 3·00%, P_2O_5 28·23%, Fe, Zn, S, traces; total, 100·00%. The sp. gr. of the mineral is 6, hardness 5, and color reddish-brown.

According to United States Consul-General Richard Guenther, of Frankfort, under date of April 7, 1902, the Brazilian Government has recently granted to a German, for 10 years, the exclusive right to develop the monazite-sand deposits along the coast of Brazil, and a company is being organized at Berlin to acquire control of this privilege and to exploit similar deposits elsewhere.

PRODUCTION OF NATURAL GAS.

By F. H. Oliphant.

The total value of natural gas produced and sold in the United States during 1900 was $23,606,463, of a quantity of the value of $23,156,616 was sold in the Appalachian and Lima-Indiana fields east of the Mississippi river, leaving $449,847 to represent the sales west of it, which amounts to less than 2% of the total sales. The value of natural gas used in the United States is gradually increasing, the production for 1901 is estimated at $27,500,000, which is almost 40% of the value of the crude petroleum produced for the same time, and represents a delivery of 171,875,000,000 cu. ft. of a fuel equivalent of 8,500,000 tons of coal. This amount of natural gas is drawn from 12,000 wells, and distributed through 24,000 miles of main line pipe from 2 to 36 in. in diameter. The consumption of natural gas in the United States has been greatly increased in those sections which are favorably located in respect to the gas supply. Although many of the older pools have been practically exhausted, newer ones are being discovered and an extension of the pipe-line systems, both in length and capacity, has been all that was necessary to maintain a supply for the increasing demand of the consumers. Kansas will show a large gain in its yield over the previous year, and West Virginia, with its immense areas of deeply buried sandstones saturated with natural gas under enormous pressure, has each succeeding year furnished an increased supply. The full value of this ever ready and convenient fuel will only be appreciated when it can no longer be obtained.

Hand in hand with the production of petroleum, that of natural gas occurs in the Appalachian and the Lima-Indiana field. The two are invariably associated, and have a common source. The gas occupies the higher portions of the arched rock-sealed reservoirs, while the petroleum, from its greater gravity, seeks the lower level in the same strata. It is to be regretted, however, that in many of the older gas fields of Pennsylvania, Ohio, and Indiana, the great natural store of this most precious fuel has already escaped through the numerous drilled wells that have punctured it, and immense quantities have been wasted by the careless and extravagant manner of its use when first introduced. The lesson of its value was learned too late in many cases to preserve but a fraction of what was originally pocketed and sealed in the reservoirs of the rocks. When first found it was allowed to blow off into the atmosphere with a noise that was appalling,

and an extravagance that was shameful. All other fuels need some preparation to fit them for combustion, but with natural gas none is necessary. The supply of gas is easily regulated, and it is ever ready as a source of the most economical power when exploded in the gas engine, and, in connection with the Welsbach mantle, is a source of a most brilliant and inexpensive illuminant unrivalled by any other artificial light. It may rightly be classed as the source of the most economical and efficient heat, light, and power known in nature. As a source of power it has been demonstrated to be more economical than the most efficient triple expansion engines, and its economical method of transportation in pipes of large and small diameters has brought it into many thousands of households in western New York, western Pennsylvania, eastern, central, and western Ohio, and eastern and northern Indiana. It is also an ideal fuel in the manufacture of steel, iron and glass, and is an ideal fuel for furnaces.

Natural gas is especially valuable to the petroleum producer. It is generally associated with petroleum, often in the upper strata of the same well, and can be taken from the casing head of the nearest producing well; it thus becomes a source of most economical power for pumping a group of wells. From 30 to 50 wells in many localities are operated by a single gas engine. There is no boiler to require the constant attention of an attendant, as all that is necessary with the gas engine is at intervals of from six to ten hours to be sure that the lubricating cups contain sufficient oil.

When the pressure has failed to some extent in the gas wells, by reason of the withdrawal of large quantities, and the capacity of the pipes to convey the gas to market thereby lessened, large pumping or compressing plants have been erected. Many of these plants are models of the highest mechanical efficiency. The more recent compressors are of large capacity, and use the natural gas itself as a motor in driving the gas to the points of consumption. These compressors dispense entirely with the boiler, develop 1,000 H.P., and weigh as much as 250 tons. A careful test made by experienced engineers of one of these large compressor engines of natural gas used in Pennsylvania, demonstrated that less than 10 cu. ft. of natural gas at or near atmospheric pressure developed 1 H.P. An illustrated description of this type of engine is given elsewhere in this section.

TABLE SHOWING THE COMPARISON OF COAL AND NATURAL GAS PER INDICATED HORSE POWER PER HOUR.

Type of Engine.	Equivalent of Gas and Coal to produce 1 H.P. per Hour.	
	Gas.	Coal.
	Cubic Feet.	Pounds.
Natural gas engine	13	1·3
Triple expansion condensing engine	16	1·6
Double expansion condensing engine	20	2·0
Single cylinder and cut-off	40	4·0
Ordinary high pressure, no cut-off	75	7·5
Ordinary oil well drilling and pumping engine	130	13·0

All natural gas has a high calorific power. It is composed of 93 to 97% of Marsh gas (CH_4) which requires for the latter percentage 10·5 times the volume

of ordinary air for complete combustion under the boiler or in the cylinder of the gas engine. Under boilers properly proportioned to their work in ordinary condition, 1 cu. ft. of natural gas has evaporated 1 lb. of water from and at 212°F., which gives 966 B.H.U. to the cu. ft., or 16 cu. ft. of natural gas equal to 15·456 B.T.U., the calorific value of 1 lb. of petroleum. Therefore 16 cu. ft. of natural gas have the same value under similar boilers, as 1 lb. of petroleum; or 16 cu. ft. of gas will equal the calorific value of 30 cu. in. of petroleum.

In the combustion of natural gas the best results have been secured from a burner with a series of small openings about 0·0625 in. ($\frac{1}{16}$ m.) to 0·1563 in. ($\frac{5}{32}$ m.) or less in diameter, under a pressure not greater than from 4 to 6 oz. to the sq. in. This is conveyed through a tube 1·5 in. in diameter and 16 to 18 in. long surrounding each jet of gas, with proper openings at the bottom of the tube to admit the air. It is constructed on the principle of the old Bunsen burner, with which every student is supplied at the beginning of instructions in analytical chemistry.

THE PRODUCTION OF NATURAL GAS IN THE UNITED STATES.

BY W. H. HAMMON.

NATURAL gas is the most perfect and convenient fuel known. It is found in nature perfectly prepared for use, stored in immense reservoirs under such high pressure that, when tapped by the drill, it furnishes the power to transport itself hundreds of miles through pipe-lines to the consumer. No artificial gas compares with it in heating power, 1 cu. ft. of it being sufficient, with proper appliances, to evaporate a pint of water. It is instantly available for use by merely turning the valve and the fire can be extinguished the moment the service is completed. When properly burned, it leaves no soot, ashes or other residue.

Among some of the nations of Asia, notably China and Persia, the use of natural gas "antedates authentic history," and in the United States, its existence has been known for more than a century. In 1775, General Washington, while locating lands received in payment for military service, visited a burning spring on the Great Kanawha river near the site of the present city of Charleston, W. Va. He pre-empted the tract containing the spring and dedicated it, together with an acre of surrounding ground to the public forever.

The first recorded use of natural gas in the United States was in 1824, at Fredonia, N. Y., where it was piped from a well to illuminate the village inn in honor of the visit of General de Lafayette.

A few years later, in 1841, William Thompkins struck a large flow of gas just above the burning spring in the Great Kanawha valley, and used the gas for heating salt furnaces. Early in the history of oil-well drilling, which began in 1859, the waste gas which almost invariably escapes from oil wells was used for firing the boilers of the drilling engines, and it was very soon piped to houses of the oil producers, where it was used for light and fuel, and large out-door flambeaus were burned at the wells. In 1872, the first natural gas plant was formed, and a 2-in. line laid from the Newton well to furnish gas for domestic use in Titusville, Pa., five and a half miles distant, but it was not until 1874

that its great value as a manufacturing fuel was demonstrated. In that year Messrs. Rodgers & Darchfield began to burn it under boilers and for all the puddling and heating furnaces in their plant at Leechburg, Armstrong County, Pa. The advantages and conveniences were at once apparent, and the use rapidly increased. By 1887, 96 rolling mills and steel works were either wholly or in part supplied with this fuel, and by 1890, it is estimated that it displaced annually 10,000,000 tons of coal.

In the earlier days of its production, the original "rock" pressure of the wells (the pressure of the reservoirs as shown by closed-in wells) was so great and the producing area so extensive that the supply of gas was believed to be practically inexhaustible. As a result the gas was wasted in the most extravagant manner. Wells were permitted to discharge their product into the air and little or no effort was made to check the flow. Frequent escape pipes and flambeaus were provided to lessen the pressure on the pipe-lines and to consume the surplus gas. No effort was made to measure the amount furnished to a consumer, and as a consequence it was burned in a very wasteful manner. However, between 1885 and 1890, the earlier fields began to show unmistakable evidences of depletion, and as a result, the gas became more valuable. Meters and other saving appliances were employed and, while the quantity of gas consumed probably decreased in five or six years to less than half the former yield, the price was increased to such a degree that the total value of the product showed but little decline. Since 1895 the value has increased, and since 1898 both the amount and value of gas consumed has increased until in 1901 the value of the product probably exceeded $25,000,000. The amount sold in 1900 was 127,000,000,000 cu. ft., and if the rate of increase continued during 1901, as the statistics of some of the largest gas companies indicate, the amount consumed was 150,000,000,000 cu. ft., equivalent to one cubic mile. The largest gas holder yet constructed is of 5,000,000 cu. ft. capacity, and the supply during 1901 would be sufficient to fill it 30,000 times, an amount which would furnish nearly 1,000 cu. ft. per month to every family in the United States.

Gas Wells.

The supply of gas is obtained from more than 10,000 wells of depths varying from a few hundred feet to more than 3,000 ft., and of an aggregate depth which would penetrate from the surface almost to the center of the earth. Three thousand miles of casing and tubing are in these wells.

The rock pressure of these wells varies greatly. In old, depleted territory it is practically nothing, and the only way of securing an additional supply is by diminishing by means of pumps the pressure at the mouth of the well below that of the atmosphere. However, in new fields, especially those drilled to the deeper sands (2,500 to 3,500 ft. deep) the pressures frequently exceed 1,000 lb. to the sq. in. Some of the largest wells known, if unconfined, would discharge into the air at least 25,000,000 cu. ft. per day, although an average "open flow" volume is probably not more than 250,000 cu. ft. The quantity actually obtained is but one-fifth of this amount, as most wells discharge against more or less line pressure and under normal conditions quite a large proportion of the wells

are "shut in" as a reserve supply until needed. The roar resulting from the "blowing off" of some of the largest wells into the open air is terrific. Formerly it was considered impossible to shut in some of the largest wells until they had become partially exhausted. It was several months after the "Big Moses" well in Tyler County, W. Va., was "struck" before it was controlled. The roar was so great that voices could not be heard within 200 ft. of the well. When the Robinson well, in Wetzel County, W. Va., was struck, six years ago, it was deemed unsafe to confine the gas, and the pipe-line was laid to the well, the connections made, and the gas turned into the line, without shutting in the well. The gate on the well was not closed until four years after it was drilled. In 1844, while drilling a salt well in West Virginia, near the burning spring referred to above, so strong a flow of gas was struck that it threw the drilling tools, weighing about 1,000 lb. out of the hole. Since then there have been several instances of much heavier tools being forced out of the hole by the pressure.

Drilling Wells.

The means employed in drilling gas wells are identical with those in use in drilling oil wells. When the location is selected a rig is erected which consists of a derrick about 80 ft. high, an engine house and a connecting belt house. From the main sill of the derrick a strong Sampson post is erected, upon which is balanced the walking beam. This is operated by the engine connected at one end, while from the other end the tools are suspended by a strong cable, one end of which passes over the crown pulley in the top of the derrick and is then attached to the bull-wheel shaft, a huge windlass at the side of the derrick. The free end passes down the well and to it the drilling tools are attached. A temper screw connects the cable and the walking beam consisting of a long screw attached to the cable, while its nut and "reins" are attached to the walking beam so arranged that by turning the screw the tools are lowered into the well. The tools proper consist of a rope socket, jars, auger stem and bit. Altogether a string of tools used for drilling deep wells is between 60 and 70 ft. long and weighs about 4,000 lb. The drilling bit is a heavy, blunt, chisel-shaped steel drill. The only other tool in the string worthy of especial mention is called the "jars"; these are two strong links arranged to admit a free vertical movement of two or three feet.

In operation, the walking beam alternately raises and lowers the tools, which are so adjusted that when the beam is at its maximum elevation, the bit is elevated about a foot above the bottom of the hole. Then as it falls, the bit first strikes the rock a sharp blow, due to its own weight and that of the stem. The slack resulting from the remaining fall of the beam is taken up in the jars, the links of which thus separate several inches. As the beam rises, the cable is first lifted until the slack in the jars is taken up when the tools receive a sharp tap which loosens the bit from the rock and permits it to rise for the next blow. As the drill cuts the rock, it is lowered by revolving the temper screw at the top of the well. When the screw is run out, the cable is loosened from the temper screw and wound up on the bull-wheel shaft, thus lifting the tools out of the hole.

The bailer is then lowered and the drillings removed. The tools are again inserted and the drilling progresses as before.

In southwestern Pennsylvania and West Virginia the hole is first made about 15 in. in diameter to a depth of about 15 ft. and a conductor inserted. Below this is drilled a hole about 13 in. in diameter through the principal Coal Measures and a 10·25-in. casing is inserted to case out the sulphur water found in the coal. A 10-in. hole is then sunk for 500 ft. to 1,500 ft. through the salt sand which frequently contains vast quantities of water and the 8·25-in. casing is inserted. Inside this is then drilled an 7-in. hole until what is known as the "Big Injun" sand is reached at about 1,500 to 2,000 ft. when the 6·625-in. casing is inserted. Below this point the hole usually remains dry, and a hole about 6·5 in. in diameter is continued to the bottom. However, it is still sufficiently large to admit of inserting a 5·1875-in. casing if the conditions should require. The cost of drilling a well, including the rig, casing, etc., varies from about $1,500 in the shallowest territory, to nearly $10,000 in the deepest sands of West Virginia.

Pipe Lines.

In the handling of natural gas a system of pipe-lines is necessary to connect the producing wells and the cities and towns where the gas is consumed, as well as an additional system to distribute the gas throughout the cities to the individual consumers. In the earlier period of the industry it was not believed possible to conduct gas at high pressure for great distances, and in the light of present knowledge it seems incredible that less than 25 years ago it was believed by a few that gas, being elastic, could not be forced through lines at high pressure, under the erroneous idea that the friction on the sides would retard the flow, while the continued inflow would increase the pressure sufficiently to burst the pipe.

In 1881, Spang, Chalfant & Co. piped gas from Millerstown, Pa., to their mills on the Allegheny river opposite Pittsburg. One of the first large gas mains of any considerable length was laid in 1882, by Mr. J. C. McDowell for the United Pipe Lines, which have since been included in the National Transit Co. It was an 8-in. line 20 miles long, connecting a well near Wilcox, with the pumping station at Colegrove, McKean County, Pa., where it supplied the boilers. About the same time, a line was laid from McKean County, Pa., to Buffalo, N. Y. Between 1882 and 1885, natural gas came into general use in most of the cities and villages of western Pennsylvania and southwestern New York.

As the adjacent fields became depleted, the gas has been brought from greater and greater distances through pipe-lines until at the present time Pittsburg is receiving gas from Doddridge County, W. Va., more than 100 miles distant; Akron and Canton, Ohio, from Wetzel County, W. Va., a distance of 150 miles; and Chicago from central Indiana. Arrangements to conduct gas more than 200 miles from the source of supply are now reported to be in progress.

The pipes used for these conductors vary in size from 2 in. to 3 ft. in diameter. For the most part the pipe is wrought iron or steel. The smaller pipes (10 in. in diameter and under) are usually made of screw-joint pipe, although in the last few years plain end pipe with couplings and rubber packing has become very popular, and is in a large measure taking the place of screw pipe, it being

equally cheap in cost and is more readily laid. Sizes from 10 in. to 2 ft. in diameter are frequently laid with "Converse" pipe, which consists of plain end pipe with the joints of heavy cast-iron sleeves or hubs fitted by molten lead which is caulked into the space between the pipe and the sleeve. The disadvantage of this joint is one common to all lead joints in that the packing material, being inelastic, becomes loosened by the settling of the pipe and by the slight movement due to changes in temperature. By a re-enforcement with rubber packing pressed against the outside of the joint by iron clamps, a very satisfactory connection is made, and frequently a pipe-line of this construction has been operated to upward of 300 lb. pressure to the sq. in. Pipes above 2 ft. in diameter are either cast-iron water-pipe or steel pipe riveted after the method of boiler plating. A line of riveted steel pipe, 36 in. in diameter, extends from Pittsburg 20 miles to the southward, and cost to construct approximately $50,000 per mile. In times of maximum demand it passes daily over 100,000,000 cu. ft. of gas.

The length of pipe of all sizes in the various transportation systems of this country is from 15,000 to 20,000 miles. In addition there are from 7,000 to 10,000 miles of pipe in the various distributing systems in cities using natural gas. Thus in the aggregate there is approximately 25,000 miles of natural gas pipe-lines in operation.

Pumping Machinery.

For the most part the power necessary to transport the gas through the pipe-lines is furnished by the natural rock pressure of the wells. In many places however the well pressures are so nearly exhausted, or the distances to be transported are so great, that this source of power is insufficient, and it is necessary to supplement it artificially by pumping. Where the pressure is small and the lift 10 lb. or less, as in drawing gas from depleted territory for nearby consumption, some form of rotary blower has been used successfully, but for higher pressures a cylinder gas compressor is necessary. Among modern gas pumping machinery are some of the finest specimens of mechanic art. Probably nowhere has a greater amount of work been done with the same expenditure of fuel than has been accomplished in gas compressors; in fact, it is doubtful if the results have been equalled in any other power plants. An indicated horse power has been maintained for one hour with less than the equivalent of two-thirds of a pound of coal. Thirty cubic feet of gas have been compressed from atmospheric pressure to 270 lb. gauge pressure with the expenditure of but 1 cu. ft. of gas in producing the power. This result was, of course, obtained only by the use of a gas engine. The importance of this new design of engine to the natural gas industry is so great that a complete description of it is warranted; the one given below has been furnished through the courtesy of Mr. E. C. Lufkin, of the Snow Steam Pump Works.

The machine illustrated by the half-tone photographic cut (Fig. 1) is designed by Mr. John S. Klein, of the National Transit Co., Oil City, Pa. This engine has four single-acting power cylinders 25 in. in diameter of bore × 48 in. stroke, two first stage compressor cylinders 31 in. in diameter × 24 in. stroke, and two second stage compressor cylinders 15·25 in. in diameter also 24 in. stroke.

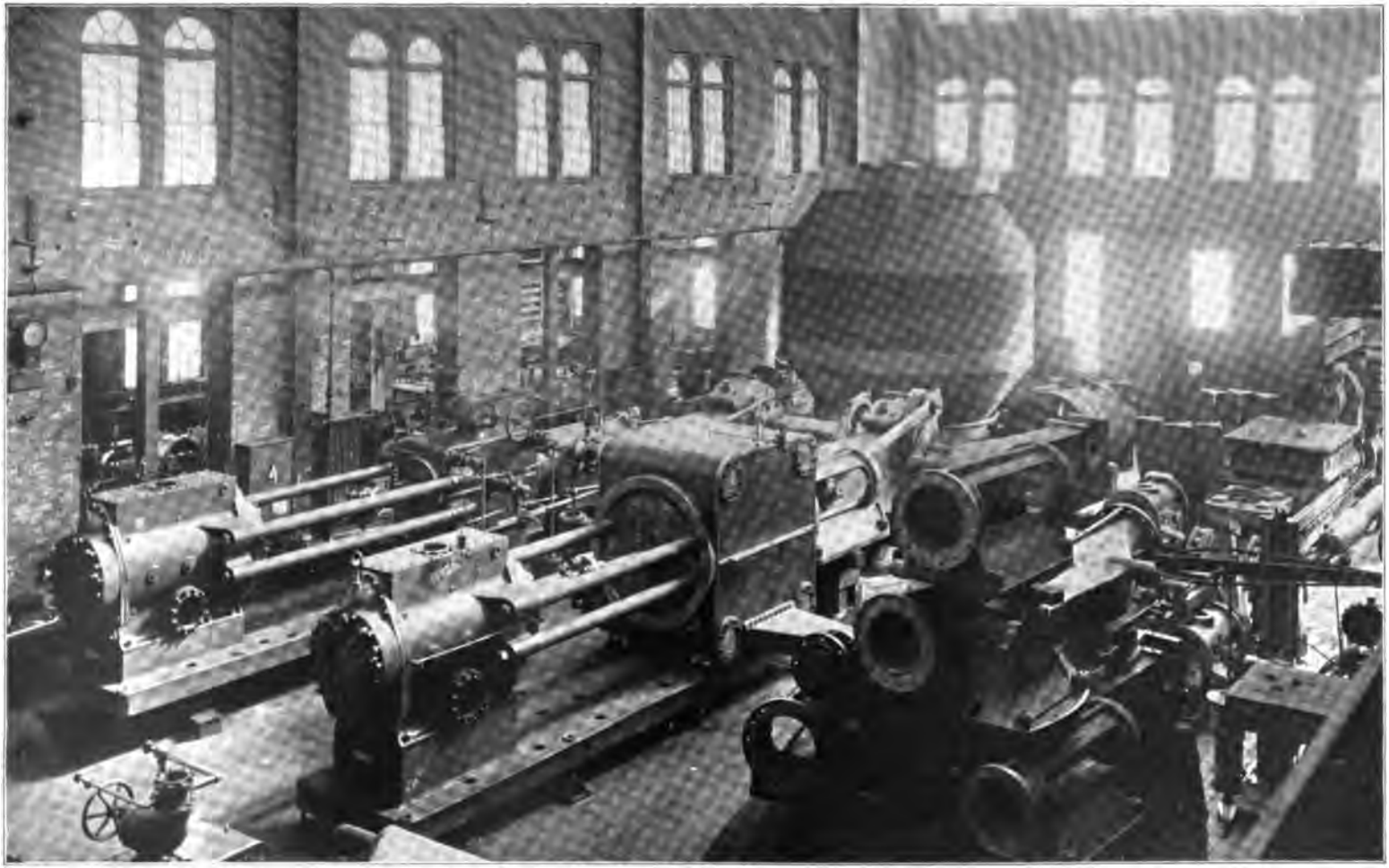


Fig. 1. Steam-driven Gas Compressor of the Carnegie Natural Gas Company, at Waynesburg, Pa.

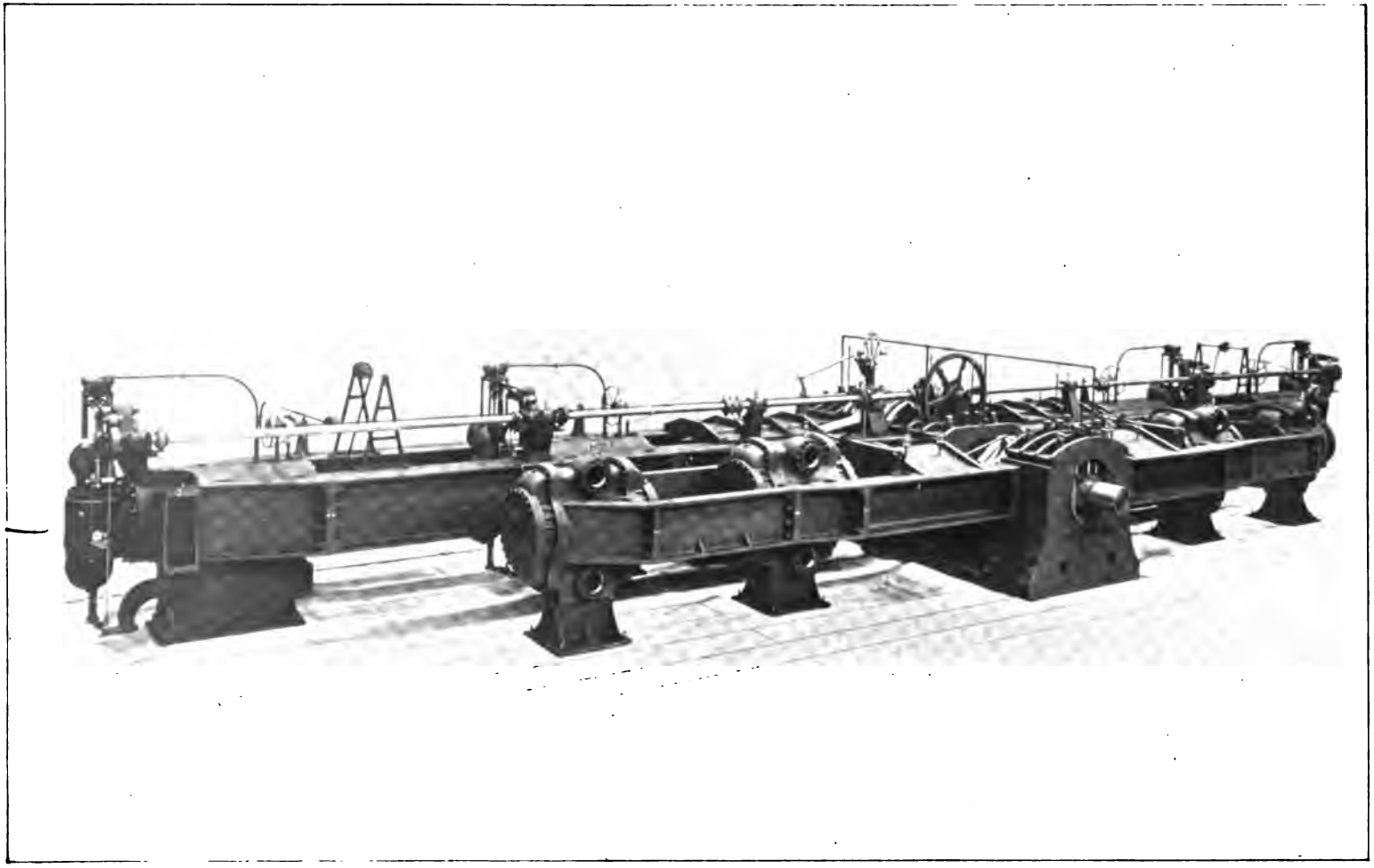


Fig. 2. 1000-H.P. Gas Compressor, operated by a Gas Engine, at Halsey, McKean County, Pa.

It will be noticed by referring to the illustration that two of the power cylinders are placed on one side of the main shaft and two on the opposite side, all being connected to the same crank pin by means of crossheads working in suitable guides and suitable connecting rods. The four power cylinders being single acting and each 4-cycle, give an impulse every stroke, so that the distribution of power is the same as though a double-acting steam cylinder were used in place of the four gas-power cylinders.

The main shaft is of the center-crank type and has two cranks, one connecting with the power cylinders and the other to the compressor pistons. The compressor crank pin stands at an angle of 90° from the power cylinder crank pin, so that the greatest turning moment derived from the power cylinders and the greatest resistance of the compressor cylinders are coincident. This arrangement necessitates the use of very small flywheels, there being two on this machine, each being 13 ft. in diameter and weighing about 37,000 lb. The connection on the latest of these machines from the outboard power piston to the inboard one is made by a central piston rod passing through a water-jacketed stuffing box in the outboard head of the inboard cylinder. The piston rod is also water-jacketed, it is hollow and forms the water-duct for the circulation of jacket water through the power pistons, which also are water-jacketed.

On the first of these machines the mixture was throttled by a speed governor so designed as to be changed for varying speeds. With this appliance every fourth stroke was an impulse stroke and the amount of mixture admitted depended upon the amount of power required to keep the speed of the engine at a constant rate. The later engines built of this type were however fitted with a cut-off valve which shut at a point in the stroke determined by the speed governor, and admitted sufficient gas to maintain constant speed.

The engines are started in the following manner: An auxiliary gas engine, placed in a separate engine house, is connected to a small mixture compressor which compresses the proper mixture of air and gas into a storage tank at about 90-lb. pressure. When it is desired to start one of the main engines, the mixture under the 90-lb. pressure is admitted to one of the power cylinders on one side of the shaft, which moves the piston over into its other extreme position. The mixture is then allowed to escape from this end of the cylinder, leaving it full of the mixture at atmospheric pressure only. The engineer then goes to one of the power cylinders on the opposite side of the shaft and admits the mixture to this cylinder forcing the piston over into its other extreme position and compressing the mixture in the cylinder in which the mixture was first admitted. The mixture is then allowed to escape from this second cylinder, leaving it full of the mixture at atmospheric pressure. The engineer then returns to the first cylinder and trips the electric igniter, combustion ensues and the engine starts, the igniter in the second cylinder being operated automatically by the movement of the engine. The machine is started in this manner with very little difficulty. The inlet and exhaust valves on the engine are steel castings, the exhaust valve being water-jacketed internally. Engines of this type are run continuously at speeds varying from 80 revolutions per minute to 120 revolutions, and indicate as high as 1,500 brake H.P. Each machine is supplied with a jacket-water

power pump driven from the main engine, which supplies jacket water to the compressor as well as the power cylinder, heads, pistons, etc. Two of these machines of an entirely new design are now being built by the Snow Steam Pump Works of Buffalo, N. Y., and each will indicate about 4,000 H.P., by far the largest gas engines yet constructed.

Many very efficient steam driven compressors are in operation, which, while not as economical as the gas engine, are models of their kind. Some plants use compound engines and burn natural gas as fuel under the boilers, sustaining an indicated horse power for an hour with 16 cu. ft. of gas. A plant of this character, pumping from atmospheric pressure to 300-lb. pressure, consumes as fuel about 8% as much gas as it compresses. Whenever it is necessary to do more work than is required to compress gas from zero to 100 lb., two compressions are made. The first raises the pressure about one-fifth and the second the remainder. It may seem difficult to understand how as much work is done in compressing gas from atmospheric pressure to 50-lb. gauge pressure as from 50-lb. gauge pressure to 250 lb. The reason is manifest when it is considered that in compressing from zero to 50-lb. gauge pressure or from approximately 15-lb. to 65-lb. absolute pressure, the gas is compressed to about two-ninths the original volume, which is about the ratio that exists between the intake and the discharge volumes in the second stage, and while the piston head is working against much higher pressures in the latter case, relatively smaller cylinders are necessary to pass the same quantity of gas under the greater pressure, so that, with the same length of stroke, the total pressure against the cylinder head is the same. Since the amount of gas that can be passed through a line between two given points depends on the difference between the squares of the initial and discharge pressures, it is evident that it is much more economical to pump the gas with one high stage compression (where lines are sufficiently tight and strong) at the initial end than to relay it with several low stage compressions. In all two stage compressions it is essential to cool the gas thoroughly between the compressions, or the pressure due to the added heat will sometimes be greater in the second stage than that due to the compression of the gas.

Gas Measurement.

There are four methods in vogue for measuring gas, namely: (1) By meters, (2) by Pitot tubes, (3) by computation from the initial and discharge pressures and size and length of pipe-line, and (4) by computing the output of the well from the volume of the hole and minute pressure.

1. Meters.—The method of measurement by meter is in most frequent use. The meters for the most part depend for their operation on two principles: one is the actual measurement of the gas by passing the whole volume through pockets or bellows of given capacity which fill and empty by the movement of a series of valves operated automatically by the flow of gas through the meter. Where the quantity of gas is so great as to need very large and expensive meters thus to measure it directly, another method—the proportional meter—is used. In this device, two routes, differing greatly in size and capacity, are available for the passage of gas through the meter. The flow through these two channels is con-

trolled by a valve in each so arranged that they operate in unison, or in such a manner that the ratio between the discharge of the two branches remains constant. One of the direct measuring meters is placed in the smaller branch and the flow through it is thus measured, from which the total amount passed by the meter is easily calculated. In general use a special dial is attached to the small meter, from which can be read the entire amount of gas passed. When gas is passed through a meter at a higher pressure than the standard at which it is sold, it is necessary to make a correction to the meter reading due to the extra pressure on the gas. The usual standard at which gas is sold is 4-oz. gauge pressure, and a simple formula for reducing to this pressure is as follows:—

$$Q=q\,\frac{p+h}{h+1},\ \text{in which}$$

Q=cubic feet of gas at 4-oz. pressure, p=gauge pressure in pounds per
q=cubic feet as shown by meter, square inch,
h=pressure of atmosphere in pounds.

Since the pressure of the atmosphere is about 14·75 lb., this becomes

$$Q=q\,\frac{p+14{\cdot}75}{15}.$$

Self-recording pressure devices can be attached to meters operating at high pressures by means of which the average pressure and the actual quantity of gas passed can be quickly determined.

2. Pitot Tubes.—The amount of gas passing through a pipe-line can be quite accurately determined by means of the Pitot tube, which consists of a small metal tube inserted in the line, having its open end turned in the direction from which the gas is flowing. This tip communicates with one branch of a glass U-tube partly filled with some liquid (generally water). The other branch of the U-tube is connected to an opening in the pipe-line, the plane of which is at right angles of that of the opening into the Pitot tube. By this means the branch connected to the Pitot tube will show a higher pressure than that connected to the pressure line, due to the force of the current of gas flowing against it. This difference of pressure will be shown by the difference in level of the liquid in the U-tube. Since this force is due to the velocity and density of the gas passing, the rate of flow can be obtained, and with frequent observations, the quantity of gas passing through the line can be readily determined. The formula of the Pitot tube as applied to gas measurement has been very carefully determined by Prof. S. W. Robinson, whose report is published in the *Geological Survey of Ohio,* Vol. 6, pp. 548-594. The final formula is:—

$$Q=1{,}690d^2\sqrt{h\ (1+\frac{p}{15})},\ \text{in which}$$

Q=number of cubic feet of gas flowing in pipe-line per hour,
d=diameter of pipe-line in inches,
p=static pressure of gas in pounds,
h=difference in level of water in U-tube, measured in inches.

This formula is computed for gas flowing through the tube at a temperature

of 40°F., but reduced to a standard temperature of 50°F. in the measurement by this formula. It is for gas of 0·60 sp. gr. To reduce to gas of any other gravity multiply the result by

$$\sqrt{\frac{0{\cdot}6}{\text{Sp. gr. gas}}}.$$

3. Computation from Pressures at Two Given Points.—It is possible to determine with considerable accuracy the quantity of gas passing through a pipe-line from the pressures at two given points when the distance between them and the size of the line are known. The formula for this purpose is:—

$$Q=40\,d^2\sqrt{\frac{(p_1{}^2-p_2{}^2)\,d}{LD}},\text{ in which}$$

Q=cubic feet of gas passing in one hour,
p_1=absolute pressure in pounds (gauge pressure+15 lb.) at initial point,
p_2=absolute pressure in pounds at discharge point,
d=diameter of pipe in inches,
L=length of pipe between points in miles,
D=density of gas.

Probably the most complete study of this method has been made by Mr. Forrest M. Towl, who has constructed a slide rule for determining at sight the discharge of any line.

4. Computation of the Output of a Well from its Minute Pressure.—A fair approximation of the output of a well at atmospheric pressure can be obtained from the capacity of the hole in cu. ft., and the increase in pressure of a well in one minute after it is shut in. The formula for the purpose is

$$Q=\frac{d^2\times 3{\cdot}1416\times L}{4\times 144}\times\frac{p}{15}\times 60\times 24,\text{ in which}$$

Q=quantity in cubic feet of gas discharged into the open air in twenty-four hours,
d=diameter of hole in inches,
L=depth of hole in feet,
p=pressure in pounds shown by gauge one minute after closing gate (less any pressure gauge might have shown before closing gate).

Reduced to lowest terms, this becomes approximately $Q=\frac{1}{2}d^2Lp$, or the output of a well in one day is equal to one-half the product of the square of the diameter of the hole in inches by the depth of the hole in feet by the pressure in pounds per sq. in. Of course, if a well is tubed, the diameter of the tubing is used instead of the diameter of the hole and if the packer is above the bottom of the hole, the capacity of the tubing to the depth of packer is first obtained and to this is added the capacity for the full size of hole for the distance from the packer to the bottom of the hole.

If the output of the well is desired at any other pressure than that of the atmosphere, the gate on well is closed as before and the rise in pressure noted for one minute from the instant the pressure reaches the desired point, this amount being used for the minute pressure.

Sources of Supply.

Geologic Sources.—Although small quantities of gas are always present in the decomposition of animal and vegetable matter, the principal sources of natural gas are from porous strata of rock, usually at considerable depth below the earth's surface. The strata are chiefly sand, gravel, shale or limestone lying between more impervious layers. Petroleum is frequently discovered in these same strata although from much more limited areas than those producing gas. The deposits are found in various portions of the world in the strata of all periods from the Silurian to the Tertiary. The great gas reservoirs overlying the Cincinnati arch are located in the Trenton and Clinton limestones of the Silurian period. Those of the Appalachian system are in the Devonian. In eastern Ohio they belong to the Sub-carboniferous period. Those of the southwestern States and California are in the Tertiary formation, as also are those of Eurasia. In the oldest formations, *i.e.*, the Trenton limestone, the gas is found in the upper layers of the limestone itself and directly underneath the Utica shales. In the Clinton limestone, the source of gas appears to be a layer of sand within the limestone. The only source of gas in the Appalachian reservoirs is from layers of sand rock enclosed by limestone or slate. In the Tertiary formation, the gas comes from beds of sand which are frequently so soft as to hardly merit the name of rock. The natural gas is usually obtained from the most elevated portions of the stratum, *i.e.*, along the anticlinals of the rock, while the petroleum collects on the lower horizon and frequently salt water is found on a still lower level along the synclinals of the rock. This anticlinal theory for the location of gas and oil is very thoroughly discussed by Prof. I. C. White, State Geologist, in the *West Virginia Geological Survey*, Vol. 1, 1899, pp. 158-180, and by Prof. Edward Orton, State Geologist, in the *Geological Survey of Ohio*, Vol. 6, p. 89 and following. The essentials of the theory are that the natural gas, being the lighter product, collects at the top of the reservoir, formed by the porous rock under the impervious layer, while the oil and water arrange themselves in the same layer in accordance with their respective gravity.

The most prolific natural gas fields thus far developed have been (1) those along the western slope of the Appalachian mountain system extending from the Canadian border to Tennessee, and (2) those throughout the great anticlinal extending from Kentucky to and even beyond Lake Erie, known as the Cincinnati arch, with its center near Cincinnati. Between these two large deposits is a marked synclinal, which, at its lowest point near the Ohio river in northwestern West Virginia, is many thousand feet below the crest of the Cincinnati arch on the one side and of the Appalachian mountain system on the other.

1. Appalachian Gas Fields.—The Appalachian gas deposits occur in the small folds or anticlinals which exist in the strata as they rise toward the Allegheny Mountains from the synclinal that lies to the westward. At the deepest place of this synclinal, in Wetzel County, W. Va., the Pittsburg coal drops almost to the level of tide-water. A few miles west of Pittsburg, the coal in this synclinal is about 900 ft. above tide level. In Armstrong County the rocks have risen 1,100 or 1,200 ft. higher, and from this region the rise is quite uniform to the New York boundary at a rate of about 32 ft. to the mile.

In lines approximately parallel with this synclinal on the one side and the ranges of the mountains on the other, are a series of small folds, the crests of which are from a few feet to 300 or 400 ft. above the adjacent synclinals, and in these small anticlinals nearly all the great deposits of the Appalachian system have been found. The illustration (Fig. 3) shows a cross-section of these strata at the outcropping of the Pittsburg coal near Pittsburg.

As has been observed in the main trough between the Cincinnati arch and the Allegheny Mountains, all the strata dipped downward in a line from the northeast toward the southwest. In the northern portion for the first 50 miles south of the New York boundary, this dip amounts to about 30 ft. to the mile. For the next 50 miles, or to about the line of Pittsburg, the dip is about 20 ft. to the mile, while south of Pittsburg it does not average more than 9 or 10 ft. to the mile.

The gas deposits of southern New York and of McKean, Elk and Warren counties, Pa., are found in several different strata of sand included in the Chemung group of the middle Devonian period. The deepest of these sands are those producing gas in Elk County, which are about 200 to 250 ft. below the Bradford sand. From the Bradford sand there is an interval of

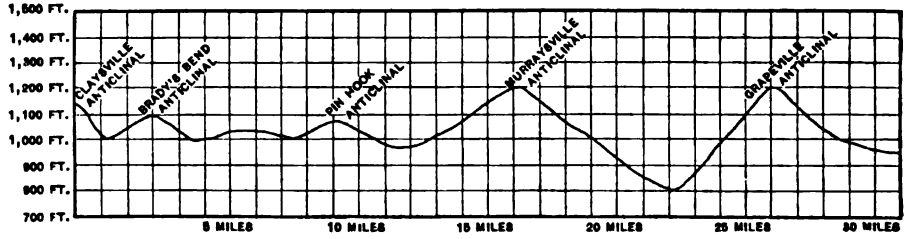


FIG. 3.—CROSS-SECTION OF STRATA AT OUTCROPPING COAL, NEAR PITTSBURG.

about 300 ft. to the Cherry Grove sand, and about 400 ft. above this is located the Warren sand. The most productive sands because of their vast extent are those of the Venango and Butler group. These are found from 600 to 1,000 ft. above the Warren group in the Catskill epoch of the Upper Devonian period. In Butler and Venango counties there are three distinct strata of these sands with an interval between them of a little more than 100 ft. Gas from some of the strata of this group has been obtained from Crawford County southward to Kentucky. The sands are known by various names in different localities. In Crawford, Venango, Butler, Clarion and Forest counties, they are known as the first, second and third oil sands. In Armstrong, Allegheny, Westmoreland and Washington counties the upper layers are known as the Murraysville or salt sand and the Hundred Foot sand, while the lower layer is broken into a number of strata known under names of Gordon, Gordon Stray and Fifth. South of the Pittsburg district, the Hundred Foot divides into the Thirty and Fifty Foot sands, and below the Gordon are found the Fourth, Fifth, Bayard and Elizabeth sands in the above order. North of Pittsburg is observed a thick layer of sandstone, the lower edge of which lies two or three hundred feet above Number One of the Venango group. This layer is about 300 ft. in thickness, and

outcrops in Butler and Venango counties, in the latter region being found only in the hill tops, from which it secured the name of Mountain Sands. From the Pittsburg region southward it is known under the name of the "Big Injun," and is productive of gas and oil in many localities.

The strata generally increase in thickness to the southward, consequently the interval between the sands becomes greater. There is an exception to this rule, however, between Green County and Wetzel County, W. Va., where the interval diminishes slightly.

2. Gas Deposits about Cincinnati Arch.—The Trenton limestone of the Silurian period has an elevation at the crest of the Cincinnati arch of more than 400 ft. above tide level. From this region it rapidly falls until at Columbus, Ohio, it is 1,200 ft. below tide level, and from thence eastward the decline is very rapid, equalling 3,000 ft. to the Ohio river at East Liverpool. To the northward it declines to about 600 ft. below tide level, where the crest of the anticlinal passes under Lake Erie in Ottawa County. At Indianapolis it is 280 ft. below tide level. From the crest of the arch, in Claremont County, just east of Cincinnati, two marked anticlinals extend, one a little east of north toward Lake Erie, and the other more marked branch extends northwestward into Indiana, apparently passing through Union, Fayette, Wayne, Henry, Delaware, Madison and Grant counties. Prof. Orton concludes that the northwestern branch was first elevated and that later there extended northwestward from it what is known as the Lima axis. Near Findlay, Ohio, this meets an abrupt terrace passing due north and south, and causes the anticlinal to change direction at that point. The vast gas deposits of Indiana and Ohio are found on the northwestern anticlinal of the Cincinnati arch and along the Lima axis and the crest of the Findlay terrace.

Besides the Trenton deposits, there are those of the Clinton limestone in Fairfield and Licking counties, Ohio, which appear to be along a terrace in that rock. Also in eastern Ohio gas is obtained from the Berea sandstone of the Subcarboniferous period.

While the principal gas deposits are along the crests of anticlinals, they are greatest where there is a considerable dip from the crest of the anticlinal downward. An essential to a gas reservoir is a layer of impervious rock above the gas horizon.

Description of Gas Deposits.

As above stated, the two great sources of natural gas on this continent are along the western slope of the Appalachian Mountains and the great Cincinnati arch. These two fields supply fully 95% of all the gas produced in North America. Besides these Kansas, Arkansas, Indian Territory, Texas, California and Colorado yield smaller quantities. The following table shows the approximate value of natural gas produced in the United States from 1892 to 1900, inclusive, and from it may be seen that the value of the gas produced in Pennsylvania has continuously exceeded that of any other State. However, for the past eight or nine years the actual amount of gas produced in Indiana has exceeded the Pennsylvania production, which is due to the fact that the price of gas obtained in Indiana has been exceedingly low. From 1888 to 1892, when the Indiana fields

APPROXIMATE VALUE OF NATURAL GAS PRODUCED IN THE UNITED STATES FROM 1892 TO 1900, INCLUSIVE. (a)

State.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.
Arkansas	$100	$100	$100	$100	$80	$40	.....	.....	.....
California	55,000	62,000	60,350	55,000	55,682	50,000	$55,337	$66,891	$79,083
Colorado	.....	.....	12,000	7,000	4,500	4,000	3,300	1,480	1,800
Illinois	12,988	14,000	15,000	7,500	6,375	5,000	2,498	2,067	1,700
Indiana	4,716,000	5,718,000	5,437,000	5,203,200	5,043,635	5,009,208	5,060,969	6,660,370	7,254,539
Kansas	40,795	50,000	86,600	112,400	124,750	105,700	174,640	332,592	356,900
Kentucky	43,175	68,500	89,200	98,700	99,000	90,000	108,133	125,745	194,032
Missouri	3,775	2,100	4,500	3,500	1,500	500	145	290	547
New York	216,000	210,000	249,000	241,536	256,000	200,076	229,078	294,598	363,367
Ohio	2,136,000	1,510,000	1,276,100	1,255,700	1,172,400	1,171,777	1,488,308	1,866,271	2,178,234
Pennsylvania	7,376,261	6,488,000	6,279,000	5,852,000	5,528,610	6,242,54[illegible]	6,806,742	8,337,210	10,187,412
South Dakota	.....	.....	.....	.....	.....	.....	.....	3,500	2,817
Texas	100	50	50	50	.....	.....	765	3,000	20,600
Utah	.....	500	500	20,000	20,000	15,050	7,875	.....	.....
West Virginia	500	123,000	395,000	100,000	640,000	912,528	1,334,023	2,335,864	2,954,083
Other States	200,000	100,000	50,000	50,000	50,000	20,000	20,000	.....	.....
Total	14,800,714	14,346,250	13,954,400	13,006,650	13,002,512	13,826,422	15,296,813	20,074,873	23,606,463

(a) From *The Mineral Resources of the United States*, 1900.

were being rapidly developed, both Ohio and Pennsylvania were producing large quantities of gas, and in order to secure the removal of manufactories to this territory, contracts at a very low price for long periods were made. In like manner, franchises for gas in Indiana cities were made which imposed conditions that were then easily complied with, but as the supply has diminished, are now very burdensome. The prices for manufacturing contracts were based on output, and for domestic consumption on the number of fires or size of openings in the burner instead of by meter. The average price of gas in this State is but little more than one-half the price of coal or wood displaced, while with equal economy its price should exceed coal owing to the greater convenience and cleanliness, a condition that is true for almost all other localities.

Pennsylvania Gas Fields.—Gas first began to attract attention as a fuel during the development of the Bradford and adjoining oil fields. In many sections in this region wells of high rock pressure and great volume were found and while the rock pressure now is, generally speaking, small, large quantities are still taken from McKean and the adjoining counties of Elk and Warren. However, before its value as a fuel was appreciated, the extensive fields about Pittsburg had been discovered. Among the first of these was at Murraysville, located 15 miles east of Pittsburg, a field of moderate depth, showing a loose sand, which yielded consequently a great volume of gas. The first well in this field, Haymaker No. 1, was opened November 4, 1878, in drilling for oil. No attempt was made to use the product of this well for four years, and very little drilling was done in the field until 1884. A short distance to the east of Murraysville was the Grapeville field, which though much smaller than the Murraysville field, contained wells of very large volume. Probably more gas was wasted from both these reservoirs than was ever utilized.

In the same month that Haymaker No. 1 was opened, the first well was struck near Tarentum, and as the supply from Murraysville and Grapeville diminished, this also was piped to Pittsburg, and as was needed, gas was brought from Canonsburg, Hickory and Venice, to the southwest. While the rock pressure is now very small in these various fields, and, while some of them have become entirely exhausted, they have showed wonderful lasting qualities. Armstrong

County has been producing gas for nearly 20 years and still yields a daily output approximating 50,000,000 cu. ft.

About 1890 the development of the territory south of Pittsburg began, although gas had already been discovered and used to considerable extent about Washington, Pa. Later the developments extended into Green and Fayette counties. At present the most prolific territory is in Green and Washington counties, where a "Bayard" sand pool was discovered in 1897. The sand lies about 300 ft. below the Gordon sand and 2,435 ft. below the Pittsburg coal. This pool has been explored from within a few miles of the West Virginia line northeastward to a point about five miles north of the Washington and Green county line. It is about 25 miles long, with a width of three or four miles. The rock pressure of the wells varied from 800 to 1,200 lb., and still shows from 400 to 1,000 lb., although the average daily output during the past two years cannot have been less than 75,000,000 cu. ft.

West Virginia Gas Fields.—In West Virginia the most prolific sands are the Gordon and those grouped near it, namely, the Gantz, Gordon Stray, Fourth, Fifth, and in some few places, the Elizabeth or Bayard sand; many large producers also have been secured from the shallower sands. Although vast quantities of gas have been taken from these reservoirs, they are the most extensive and prolific known at present. Vast areas of natural gas deposits exist in Wetzel, Marshall, Marion, Monongalia, Tyler, Harrison, Doddridge, Lewis, Ritchie, Gilmer and Calhoun counties, and many others farther south. Wells have been drilled which show rock pressures exceeding 1,200 lb. and volumes of from 12,000,000 to 20,000,000 cu. ft. per day, while some have been estimated as high as 50,000,000 cu. ft. If this supply is properly conserved, it will furnish vast quantities for many years, not only for local consumption, but for transportation to markets in Ohio and Pennsylvania which are now being supplied for the most part from the less distant fields. Unfortunately for the preservation of the gas, the deposits are almost invariably associated with oil pools, from which the gas is discharged with the oil, and in the past, little effort has been made to restrain its flow. From one region in Wetzel and Tyler counties, embracing 100 square miles, with an original rock pressure of about 1,000 lb., fully one-half of the entire supply has been wasted. It is a matter of regret that there is no satisfactory legal protection for this product. However the value of gas is now becoming so universally understood and the principal oil producers are either directly or indirectly interested in the gas companies, so that the former waste has very appreciably decreased and there is reason to believe a new era of economy in gas production and preservation has begun.

Ohio Gas Fields.—The chief supply of gas in this State, *i.e.*, the reservoir in the Trenton limestone, has been practically exhausted. This field originally embraced 500 or 600 square miles in the northwest portion of the State and had a uniform rock pressure of over 400 lb. At present the pressure is nearly exhausted, and the wells drowned out with salt water. In the eastern portion of the State quite a large quantity of gas was obtained from the Berea sandstone. However, the only source of any considerable supply at present known in the State is the Sugar Grove field south of Lancaster and the recently discovered

Licking County field to the north of it. The gas in these fields comes from wells in the Clinton limestone 2,000 ft. or more in depth and showed originally about 750 lb. pressure. The Sugar Grove field was first opened in 1887 and already shows no more than one-third of the original rock pressure. The amount of gas produced in Ohio reached its maximum in 1888 or 1889. From thence it steadily diminished until 1897, although later the production has increased considerably and the value of the product has nearly doubled. This increase in value has been due in a measure to a more economic method of handling resulting from an extensive adoption of the meter system of measurement. It seems probable however that the maximum production has about been reached and existing companies are making extensive preparations for securing large quantities of gas from West Virginia.

Indiana Gas Fields.—The productive area in this State originally extended over an area of between 2,500 and 3,000 square miles, located from the center of the State eastward and northward to the Ohio boundary. The source was from the Trenton limestone. Originally the fields showed a nearly uniform rock pressure of 325 lb., which now varies from zero to 150 lb. For the past nine years this State has produced more gas than any other, but the fields have become greatly depleted. Large compressing plants are installed to diminish the line pressure at the wells and to furnish power to transport the gas to points of consumption. It would seem that these more and more expensive methods of gas production must soon prevent the successful conduct of the gas industry in many portions of this territory unless relief is obtained from the uneconomic methods of consumption due to lack of meter measurement and a price obtained for the product more commensurate to its value.

The Origin of Natural Gas.

Many theories of natural gas have been advanced, but the one which meets with most general acceptance is that propounded and discussed so ably by Prof. Edward Orton, in the *Geological Survey of Ohio.* Briefly stated, the theory is that gas and petroleum are the results of decomposition at moderate temperature of vegetable and animal matter, chiefly in the stratum where found. There seems to be little doubt expressed at present that its source is organic rather than inorganic, and while there are many adherents to the theory of distillation by heat, this latter theory is losing ground because, as a rule, there are no noticeable evidences of heat and furthermore it can be shown that a process of this character is unnecessary.

Cause of Rock Pressure.

Prof. Orton advocates that the pressure is hydrostatic, being due to the head of water which is entering the sands at the outcroppings or through breaks into other saturated layers, and showed in proof of this claim (1) that the pressure of the wells of the Trenton limestone agreed exactly with that which would result from a head at the level of Lake Erie, and (2) that water follows the gas into the rock as the gas is exhausted. However, Prof. I. C. White calls attention to the fact that at points in New York, Pennsylvania and West Virginia, the rock

pressure exceeds any possible artesian pressure, and further, the sands as depleted continue dry, which shows no evidence of communicating with water. In these cases, at least, it would seem that the pressure was due solely to the vast accumulations of gas.

Chemistry of Natural Gas.

Natural gas is composed principally of the gaseous hydrocarbons of the paraffine group, whose general formula is C_nH_{2n+2}. Besides the paraffines, there are small but varying amounts of the following gases: nitrogen (N), carbonic acid gas (CO_2), olefiants, oxygen (O), ammonia (NH_3), hydrogen sulphide (H_2S) and hydrogen (H). The paraffines however amount to 90 or 95% of the entire volume of the gas, and consist principally of marsh gas or methane (CH_4). Frequently it is the only member of the series present. It seems difficult to separate the various members of this group, but the presence of the heavier members is frequently shown by the increased gravity, the increased heat units in its combustion and by the smaller proportion of water to carbonic acid gas in the products of combustion. The following table of the properties of the first three members of the paraffine group (the ones most frequently present) has been compiled from data in Schorlemmer's *Hand Book of Chemistry* and from the work of Prof. F. C. Phillips, which is published in the *Pennsylvania Geological Survey,* 1892.

PROPERTIES OF THE THREE LIGHTER MEMBERS OF THE PARAFFINE GROUP.

Name.	Chemical Formula.	Carbon by Weight.	Hydrogen by Weight.	Specific Gravity.	Weight per Cu. Ft.	Liquefying Pressure.	No. B. T. U. per Cu. Ft.a
		%	%		Lb.	Lb.	
Methane (marsh gas)...	CH_4	74·97	25·03	0·553	0·0446	2,650 at 10° F.	1,064
Ethane.....	C_2H_6	79·96	20·04	1·084	0·0837	676 at 39° F.	1,863
Propane.....	C_3H_8	81·78	18·22	1·45	0·12808	550 at 39° F.	2,662

(a) B. T. U.—British Thermal Units or amount of heat necessary to raise one lb. of water at 39° F. through 1° F.

It is observed that the lower members of the series increase in specific gravity and in available heat units at a fairly constant ratio, each member yielding approximately 800 heat units to the cubic foot more than the one preceding. It should be observed also that the pressure on many natural gas reservoirs exceeds the liquefying pressure of the gas in all but the first member of the group. Consequently in such reservoirs all ethane and propane exist as a liquid, and are only vaporized at the bottom of the well as the pressure is reduced at that point. Since these gases are much richer in heat units than methane, it would seem probable that as the pressure of gas fields containing these liquids depletes a large proportion of them would vaporize and result in a richer gas being produced than in earlier stages of production. The next lower member, butane, of the series remains, in its normal state, a liquid at atmospheric pressure and 33°F. and consequently does not vaporize in large quantities under normal line pressure. The boiling points of the remaining members of the group are sufficiently high to preclude any large amount of their vapors being present in the gas.

Besides the paraffines, small quantities of the illuminants, or the olefiant series

(C_nH_{2n}), have been observed. About the only member of which an appreciable amount has been observed is ethylene (C_2H_4). The analyses of gases from the Trenton limestone in Ohio and Indiana as given in the *Geological Survey of Ohio*, Vol. 6, page 137, show about 0·25% of olefiants.

The subjoined tables give a number of analyses of natural gas from various fields in New York, Pennsylvania, West Virginia, Ohio, and Indiana.

ANALYSES OF NATURAL GAS OF NEW YORK AND PENNSYLVANIA, MADE BY PROF. F. C. PHILLIPS.

	Fredonia, N. Y.	Sheffield.	Kane.	Wilcox	Speechly.	Murraysville.	Raccoon Creek.	Baden.	Houston.
	%	%	%	%	%	%	%	%	%
Nitrogen	9·54	9·03	9·79	9·41	4·51	2·02	9·91	12·32	15·30
Carbonic acid	0·41	0·80	0·20	0·21	0·05	0·20	Trace.	0·41	0·44
Hydrogen	0·00	0·00	0·00	0·00	0·02	0·00	0·00	0·00	0·00
Ammonia	0·00	0·00	0·00	6·00	0·00	0·00	0·00	0·00	Trace.
Oxygen	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Hydrogen sulphide	0·00	0·00	0·00	0·00	0·00	0·00	Trace.	0·00	0·00
Paraffines	90·05	90·64	90·01	90·38	95·42	97·70	90·09	87·27	24·26
Total	100	100	100	100	100	100	100	100	100
Per cent. by weight of carbon	78·14	76·69	76·77	76·52	77·11	74·96	76·42	76·42	76·68
Per cent. by weight of hydrogen	21·86	23·31	23·23	23·48	22·89	25·04	23·58	23·52	23·32
B. T. U. per cu. ft.	1,287	1,128	1,163	1,115	1,252	1,044	1,095	1,069	1,087

ANALYSES OF TRENTON LIMESTONE GAS, MADE BY PROF. C. C. HOWARD.

	Fostoria, Ohio.	Findlay, Ohio.	St. Marys, Ohio.	Muncie, Ind.	Anderson, Ind.	Kokomo, Ind.	Marion, Ind.
	%	%	%	%	%	%	%
Hydrogen	1·89	1·64	1·74	3·25	1·86	1·42	1·20
Methane (marsh gas)	92·84	93·35	93·95	92·67	93·07	94·16	93·58
Olefiant	0·20	0·35	0·20	0·25	0·49	0·30	0·15
Carbon monoxide	0·55	0·41	0·44	0·45	0·73	0·55	0·60
Carbonic acid	0·20	0·25	0·28	0·25	0·26	0·29	0·30
Oxygen	0·35	0·39	0·35	0·35	0·40	0·30	0·55
Nitrogen	3·82	3·41	2·96	3·53	3·02	2·80	3·42
Hydrogen sulphide	0·15	0·20	0·21	0·15	0·15	0·18	0·20
Total	100·00	100·00	100·00	100·00	100·00	100·00	100·00

ANALYSIS OF WEST VIRGINIA GAS, MADE BY MR. FORREST M. TOWL.

	Parkersburg.	Wetzel County.
	%	%
Carbon dioxide	0·7	0·2
Illuminants	0·7	0·6
Petroleum vapors	1·5	0·0
Oxygen	1·8	0·5
Nitrogen	0·0	0·1
Paraffines	95·3	98·6
	100·0	100·0
Specific gravity	0·70	0·674
B. T. U. per cu. ft.	1,153	1,141

Combustion.—It will be observed that few attempts have been made to separate the hydrocarbons. The process is very difficult and unsatisfactory and as the chief and only use of gas is for fuel, the principal point to be considered is its heating power. (Its use as an illuminant is limited to the application to incandescent mantels, where the light is dependent on the heating power of the gas.) This subject has been very carefully considered by many of the best

chemists and physicists, notably Prof. C. C. Howard, in Ohio; Mr. Robert Young and Prof. F. C. Phillips, in Pennsylvania; Forrest M. Towl, and many others. The difference in their results are due mostly to differences in methods of analysis. For all practical purposes the following rule will give British Thermal Units (B. T. U.) per cubic foot: B. T. U.=per cent. of hydrocarbons × specific gravity of gas × 18·3.

This formula is only a rough approximation, but gives a result slightly too small with gas of low specific gravity and correspondingly higher with the heaviest gases.

The products of the combustion of hydrocarbons vary in proportion to the amount of oxygen available for the combustion. If sufficient oxygen is supplied, the resultant products are steam (H_2O) and carbonic acid gas (CO_2). If the supply is insufficient, carbon is burned to carbon monoxide (CO) with a loss of more than one-half of the heat units in the carbon. If the amount of oxygen is still less, the hydrogen will burn to steam and the carbon be deposited as soot, and in the last named case, nearly one-half of the heat units of the carbon will be lost.

To burn marsh gas in oxygen, the formula is:—

$$CH_4+2O_2=CO_2+2H_2O$$

or 1 cu. ft. of marsh gas requires 2 cu. ft. of oxygen to burn it, the results produced being 1 cu. ft. of carbonic acid gas and 2 cu. ft. of steam.

To burn ethane, the chemical formula is:—

$$2C_2H_6+7O_2=4CO_2+6H_2O$$

or 2 cu. ft. of ethane requires 7 cu. ft. of oxygen to consume it. Since the source of oxygen commonly used in combustion is the air, of which but 21% by volume is oxygen and 79% is innate nitrogen, about 5 cu. ft. of air is necessary to furnish 1 cu. ft. of oxygen, or approximately 10 parts by volume of air are necessary to burn one of methane and 17·5 parts to burn one of ethane.

As an example in combustion, suppose it is desired to burn gas under boilers for making steam, the composition of the gas being 95% paraffines, of which 25% is ethane and 70% methane. Suppose the stack temperature to be 400°F. and the temperature of the air 60°F. There would be available in 1 cu. ft. of this gas.—

Methane, 70% of 1,064=744·8 B. T. U.
Ethane, 25% of 1,863=465·6 B. T. U.
Total, 1,210·4 B. T. U.

To burn this gas would require of air:—

70% of 10 cu. ft.=7 cu. ft.
25% of 17·5 cu. ft.=4·4 cu. ft.
Total, 11·4 cu. ft.

This would weigh 11·4×0:08071 (weight of 1 cu. ft. of air)=0·92 lb. To this must be added the weight of 1 cu. ft. of the gas, or about 0·056, making 0·976 lb., or in addition to the work done in evaporating water in the boiler, each cubic

foot of gas must raise 0·976 lb. of the gaseous products of combustion from 60°F. to 400°F. or through 340°F. Since the average specific heat of the products of combustion is about 0·24, this work will consume

$$0{\cdot}976\times0{\cdot}24\times340=79{\cdot}6 \text{ B. T. U.}$$

Subtracting this amount from the heat units in a cubic foot of the gas, we have 1,210·4—79·6=1,130·8 B. T. U. still available for evaporating water. If the temperature of the feed water be 80°F., it will take 212—80=132 B. T. U. to raise the temperature of 1 lb. of water to the boiling point and, since 965·7 B. T. U. are necessary to convert 1 lb. of water at 212°F. into steam of the same temperature, there will be necessary 965·7+132=1,097·7 B. T. U. to convert 1 lb. of water 80°F. into steam at 212°F., or the heat of 1 cu. ft. of gas would be sufficient to evaporate 1,130·8÷1,097·7=1·03 lb. of water from 80°F. to steam at 212°F. If the water was at 212°F. in the beginning, 1 cu. ft. of gas would convert 1,130·8÷965·7=1·17 lb.

Of course, in practice considerable heat is lost by radiation and other causes, and the above-mentioned conditions are not realized. However in a number of instances 1 lb. of water has been evaporated from a temperature of 212°F. for each cu. ft. of gas consumed. In December, 1900, at Tarport, Pa., 1 cu. ft.[1] of gas with Klein burners evaporated 1·15 lb. of water under 80 H.P. boilers.

Uses of Natural Gas.

Natural gas is most valuable as a domestic fuel. For heating dwellings it is the ideal fuel, being perfectly clean, without dust or soot, operated without labor, and with a thermostat connection for regulating the feed of gas by the temperature of the room it operates from week to week without attention and without any variation in the temperature of the apartment. For cooking it is unsurpassable. Besides being cleanly, it makes an extremely hot fire, is always at hand in a moment, and can be extinguished immediately when not needed. It permits the kitchen to be cool and clean, and with an over thermometer, the baking temperature can be controlled to a single degree. In roasting and broiling a quick hot fire over the meat sears the outside and results in a sweeter, more juicy and heavier roast than is possible by any other means.

With reference to economy, natural gas at 25c. per 1,000 cu. ft. is as cheap for domestic heating and cooking as anthracite coal at $5·50 per ton.

For manufacturing purposes it is probably most valuable in the manufacture of glass where its advantages are the reduction in labor in caring for furnaces; the improved quality of the product, due to the freedom from dust or soot to discolor it; and the longer life of the furnaces.

In the heating and melting of iron and steel, there is less wear on the furnaces and smaller furnaces can be used for the same output than is possible with coal. It is economical and advantageous to use natural gas in annealing furnaces, tool heating and welding furnaces, core ovens, heating furnaces where blasts are used, and in all kinds of gas regenerating furnaces for heating and melting purposes.

In burning brick, a better color can be obtained and a better output from the

[1] *Mineral Resources of the United States*, 1900, p. 684.

kiln because the fire is regulated more quickly and easily than with coal. In fact, natural gas is useful for nearly all purposes where coal may be used, except in the reduction of iron ore, where its composition and gaseous nature preclude its use.

Burned under boilers, with the most economic burners, natural gas at 10c. per 1,000 ft. is about as economic as coal at $1·20 per ton, even though the coal be burned in the most economic manner with mechanical stokers.

NICKEL AND COBALT.

As in previous years the domestic production of nickel and of cobalt oxide in the United States has been derived as by-products from the treatment of lead ores at Mine La Motte, Mo. The production of metallic nickel from domestic ores in 1901 amounted to 6,700 lb., as compared with 9,715 lb. in 1900, showing a decrease of 3,015 lb.; while the production of cobalt oxide in 1901 was 13,360 lb., against 12,270 lb. in 1900, an increase of 1,090 lb. There has been considerable prospecting for nickel ores in many widely separated localities in the United States, and while exploitation has been active, no production of nickel ores on a commercial scale resulted during 1901. Development work has been carried on with more or less promise at the following localities:—

Arizona.—In Pima County a new deposit of nickel ore is being exploited.

Idaho.—At St. Joe mine, Blackbird, an arsenical pyritic mineral was reported, samples of which assayed as high as 8% nickel.

Nevada.—At Lovelocks Station, operating in the deposits of nickel and cobalt arsenides; at Bunkerville, operating in deposits similar to the Sudbury (Ontario) ores, and near Candelaria a deposit of nickel ore has been reported.

North Carolina.—Near Morgantown, in the western part of the State, a deposit of nickel ore somewhat similar to the New Caledonia ore is being opened up.

Oregon.—A high-grade cobalt ore deposit is being developed in the eastern part of the State.

Wyoming.—At Piney Creek, in the northern portion of the State, the occurrence of nickel ore has been noted.

UNITED STATES PRODUCTION, IMPORTS AND EXPORTS OF NICKEL.

Year.	Production.						Imports. (c)		Exports. (d)	
	From Domestic Ore		From Foreign Ore.							
	Metallic.		Ni in Sulphide, Oxide, etc. (a)		Metallic.					
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Long Tons.	Value.	Pounds.	Value.
1897.....	33,700	$11,668	1,459,390	$505,214	2,646,000	$913,968	(b) 79	$53,013	4,955,558	$997,391
1898.....	11,145	3,845	3,516,427	1,213,167	3,611,357	1,245,918	17,819	1,020,932	5,657,618	1,359,609
1899.....	22,500	8,156	3,008,122	1,088,632	5,045 221	1,828,838	19.687	1,101,989	5,004,377	1,151,923
1900.....	9,715	4,584	3,605,138	1,682,520	4,107,982	1,915,193	25,670	1,183,884	5,869,906	1,362,797
1901.....	6,700	3,551	4,653,337	2,168,455	4,011,277	1,869,255	52,111	1,687,166	5,869,655	1,521,291

(a) The nickel reported as in oxide is now mostly converted into metal before consumption. (b) Includes nickel, nickel oxide, and alloys of any kind in which nickel is the chief element of value, but not manufactures, ore, or matte. (c) Ore and matte. (d) Comprises domestic nickel, nickel oxide, and matte.

Market.—The demand for nickel in the early part of 1901 was brisk and heavy purchases were made; the consumption, however, was disappointing, and at the end of the year consumers had considerable stock on hand. Trade was brisk and the price was steady throughout the year, ranging from 50 to 60c. per lb., depending on the size of the order. In this connection it should be noted that by far the greater part of the output is sold at private sale at an average price much lower than that reported as the market price.

UNITED STATES PRODUCTION AND IMPORTS OF COBALT OXIDE.

Year.	Production	Imports.		Year.	Production	Imports.	
	Pounds.	Pounds.	Value.		Pounds.	Pounds.	Value.
1896	12,825	27,189	$36,212	1899	10,200	46,791	$68,847
1897	19,300	24,771	34,773	1900	12,270	54,073	88,551
1898	9,640	33,731	49,245	1901	13,360	71,969	134,208

A very important step in the development of the nickel industry was made early in April, 1902, by the organization, under the laws of New Jersey, of the International Nickel Co., which resulted from plans to consolidate and control the nickel production of the world. The capitalization of the International Nickel Co. consists of $12,000,000 common stock, $12,000,000 preferred stock carrying 6% dividends non-accumulative, and $12,000,000 of 30-year 5% gold bonds. Of this total capital, $9,000,000 of common stock, $9,000,000 of preferred stock, and $10,000,000 of bonds was issued for the purchase of the following properties in the United States, Canada, and New Caledonia: The Canadian Copper Co; the Orford Copper Co., with reduction works at Bayonne, N. J.; the Anglo-American Iron Co. and the Vermillion Mining Co., in Canada; the American Nickel Works, in Camden, N. J.; the Nickel Corporation, Ltd., and the Société Minière Caledonienne, in New Caledonia. The Société le Nickel, owning extensive properties in New Caledonia and a reduction plant in France, is not included in the combination, although it is believed that an understanding exists between them which will regulate the production and price of nickel, together with the apportionment of the trade. Other companies owning properties in the Sudbury district, Canada, not in the combination, are: The Mond Nickel Co., with a refining plant in England; the Lake Superior Power Co., with a refinery in course of construction at Sault Ste. Marie, and the Nickel Copper Co., of Ontario, with a refining plant at Hamilton. The extended use of nickel steel explains the interest in the International Nickel Co., taken by the United States Steel Corporation, although no official connection exists between the two companies.

In Germany the firm of Basse & Selve produces nickel from Norwegian and New Caledonian ores and occasionally from copper matte. In addition to this firm there are one or two nickel refineries of lesser importance. The International Nickel Co. and the Société le Nickel will control in the near future by far the greater part of the production of metallic nickel in the world.

Austria.—The production of the Martha and Benno nickel mines in the district of Frankenstein, Silesia, has risen very rapidly from 80 tons of nickel ore in 1899 to 3,896 in 1900, and it is estimated that the 1901 production is much

THE WORLD'S PRODUCTION OF NICKEL. (METRIC TONS.)

Year.	From New Caledonian Ores.					Canada. (b)	Norway.	United States.		World's Total.
	Prussia.	France.	England	United States.	Total.			Domestic	Imported	
1897.....	898	1,245	715	.....	2,858	1,813	*Nil.*	15	1,859	4,686
1898.....	1,108	1,540	960	.....	3,608	2,508	*Nil.*	5	3,234	6,116
1899.....	1,105	1,740	1,000	.....	3,845	2,605	(a)	10	3,651	6,460
1900.....	1,370	1,700	1,600	(d)	4,676	3,212	(a)	4	3,499	7,892
1901.....	(a)	(a)	(a)	1,796	6,202	4,169	(c) 27	3	3,643	10,401

(a) Individual statistics not yet reported. (b) Nickel in ore and matte, nearly all the Canadian nickel is refined in the United States. (c) Nickel in Norwegian ore, included in U. S. production from imported ores. (d) Statistics not available.

NOTE.—The figures for France and Prussia are from official reports; the amount credited to England has been obtained by deducting the output in France from the combined output of the French and English works as given by the *Metallurgischegesellschaft, A. G.*, except in 1899, when the English production was reported separately. The actual output of all English works is somewhat greater than the above amounts as a little Canadian ore is smelted there. The Prussian figures include a small amount of nickel of domestic origin. The Canadian figures are those of the Geological Survey of the Dominion. The world's total has been arrived at by adding the production from New Caledonian ores, the output of Canada and Norway, and the domestic production of the United States. In 1899, however, the total represents the total output in the United States and the production from New Caledonia ores, since the imports into this country were not derived from Canada alone.

larger. Late in 1900 a Robert-Stollen smelting furnace with a daily capacity of 25 tons was erected and in operation during the year.

Canada.—According to the report of the Dominion Geological Survey, the production of nickel in Ontario in 1901 was 9,189,047 lb., valued at $1,859,970, against 7,080,227 lb., valued at $3,327,707 in 1900. The detailed statistics of Ontario, compiled by A. Blue, Esq., director of the Ontario Bureau of Mines, are as follows:—

Schedule.	1896.	1897.	1898.	1899.	1900.	1901.
Ore raised.....Short tons	109,097	93,155	123,920	203,118	216,695	226,945
Ore smelted.....Short tons	73,505	96,093	121,924	171,230	211,960	270,380
Per cent. nickel.....	2·67	2·08	2·28	.....	1·67	.....
Per cent. copper.....	2·54	2·86	3·43	.....	1·59	.....
Ordinary matte.....Short tons	9,733	13,706	21,101	19,109	23,336	29,588
Bessemerized matte..Short tons	.....	328	.....	106	112	15,546
Nickel content.....Short tons	1,949	1,999	2,284	2,873	3,540	4,441
Copper content.....Short tons	1,868	2,750	4,187	2,834	3,364	4,197
Value of nickel.....	$357,000	$359,651	$514,220	$526,104	$756,626	$1,859,970
Value of copper.....	130,660	200,007	268,080	176,236	319,681	589,080
Wages paid.....	247,151	253,223	315,501	443,879	728,946	1,045,869
Men employed.....	485	535	637	839	1,444	2,284

In connection with the development of the nickel industry in Canada there was considerable agitation in Parliament during 1901 over the proposed Acts affecting the levy of an export duty on the copper nickel products of Ontario. These Acts, though passed by their respective parliaments, are not yet operative, as the necessary proclamations have been withheld awaiting the decision of the Supreme Court of the Dominion of Canada, to which the matter has been referred on appeal. The Acts referred to are:—

1. That passed by the Dominion of Canada (Chapter 17 of 60-61 Victoria) giving the Governor-General power to levy an export tax on copper nickel products of Ontario. The export duty, as passed by Parliament, is as follows:—

"On nickel contained in matte or in the ore or in any crude or partially manufactured state, and upon copper contained in any matte or ore which also contains nickel, when exported from Canada, upon such nickel an export duty not exceeding 10c. per lb., and upon such copper an export duty not exceeding 2c. per lb."

2. That passed by the legislature of Ontario, amending the Mines Act (Chapter 13 of 63 Victoria) providing for an export duty as follows:—

"For ores of copper, $2 per ton, or $25 per ton of metal contents if partly treated or reduced; for ores of nickel, $10 per ton, or $60 per ton of nickel contents if partly treated or reduced; for ores of copper and nickel, $7 per ton, or $20 and $50, respectively, per ton of metal contents of copper and nickel if partly treated or reduced."

These duties require a proclamation by the Lieutenant-Governor before becoming operative.

With the exception of 1,147 short tons of copper-nickel matte, which was produced by the Mond Nickel Co., at Victoria mines and shipped to England, the entire Canadian production of matte during 1901 was refined in the United States, which amounted to 58,364 short tons, containing 4,768 short tons of metallic nickel. It was with a view to develop the refining of copper-nickel matte in Canada that the Acts of Parliament were made. Heretofore, however, experiments conducted to this end by the Canadian Copper Co. and others have not resulted satisfactorily from a financial standpoint, and this fact, coupled with the shipment of nickel ores from New Caledonia and Norway and the active exploration of nickel fields in the United States, renders the proposed legislation of doubtful value to Canadian interests.

(By A. McCharles.)—For several years before 1901 the operations of the nickel mines of the Sudbury district were confined to the efforts of one company, the output each season varying little from the previous one, but with the completion of the Mond Nickel Co.'s plant in May, 1901, and the successful operation of its plant at the rate of from 150 to 200 tons of ore per day since that time, a new and more progressive epoch has been initiated. The Victoria mine of this company has been exploited systematically to the fifth level in solid massive ore, and to one side of the main deposit a large independent body of similar ore has been found. The ores average 3% Ni and 3% Cu, a content considerably above the paying point. Another property belonging to the same company is in the township of Garson, 9 miles to the northeast of Sudbury, which is but little developed for lack of railway facilities.

The Lake Superior Power Co., of Sault Ste. Marie, has been opening the Gertrude mine, at Creighton, for a number of years, although but a few carloads have been shipped for experimental purposes. In 1901 the company purchased the Elsie mine, at McKim, and the Jarvis mine, near Lake Wahnapitae, all containing high-grade nickel ore. The Gertrude and the Elsie mines have contributed about 15,000 tons of ore to the roast heaps during the past year. Most of the output of these mines will be converted into matte at the three-furnace smelting plant which will be erected during 1902, near the Gertrude mine, instead of shipping to Sault Ste. Marie, as was at first intended. In the building of the first section of the Manitoulin & North Shore Railway from Sudbury to the Gertrude mine the Lake Superior Power Co. has accomplished an exceptional improvement of the Sudbury district; the first section, while but 13 miles in length, passes close to six good mines, one of them containing the largest ore body of the district, and although but three of these mines were operated during

1901, the road is said to have paid well during the year. Eventually the road will traverse the entire nickel range almost from end to end.

The last year of the independent existence of the Canadian Copper Co. was the busiest of its 15 years of history. The capacity of the smelting plant was almost doubled during the year, but owing to the opening of the Creighton mine, undoubtedly the greatest deposit of nickel-copper ore in the district, the smelter was unable to treat all the ore available.

The mining operations of the Nickel-Copper Co., of Hamilton, have come to an unfortunate end owing to the complete failure of the new self-roasting process plant erected at Worthington Station.

New Caledonia.—The Société le Nickel during the latter part of 1901 started the erection of a new blast furnace plant at Thio, on Mission Bay, but made little progress owing to trouble with the imported Japanese laborers. During the year some work was done on the nickel mines of the Canala district, and a little development was also accomplished on the cobalt mines of Bogotha Peninsula. Early in 1902 considerable development work was initiated in the Thio district. Messrs. Bardey & Roland purchased the Prise dè l'Alma, and the Prise de Rivoa mines, near Port Bouquet, which will be actively worked during the year. M. Bruthiaux has begun work on the Puy-de-Dome mine at Kuakue, and a tramway 3 km. in length is under construction to convey ore from the mines to Port Bouquet. The exports of nickel ore from New Caledonia in 1901 were 133,098 metric tons, as against 100,318 metric tons in 1900, while exports of cobalt ore were 2,872 and 2,437 metric tons, respectively. Smelting and refining works for the New Caledonia ores were erected at New Castle, New South Wales, and extensive beds of nickel ore are reported to have been discovered in the colony of New South Wales.

(By F. Danvers Power.)—The only nickel ore that occurs in New Caledonia is the hydrated silicate of nickel, free from sulphur, arsenic or copper, in which more or less of the nickel oxide is replaced by magnesia, ferric oxide and alumina. Mr. T. Moore, of Noumea, gives this mineral the formula $7NiO{\cdot}6SiO_2+H_2O$. The mineral occurs in two forms: the usual green noumeaite, which is classed in works on mineralogy as amorphous, but acicular and blade-like crystals of which have been found at Dumbea; and the "chocolate nickel," which looks, both in color and grain, like cake chocolate, hence the name. The green ore, which when pure contains from 45 to 48% NiO, merges into the brown, which in the pure state carries 43·5 to 46% NiO. At first the "green nickel" was mistaken for copper carbonate, while the "brown nickel" was thrown away as worthless earth. The darker the mineral, whether green or brown, the richer it is in nickel. The noumeaite was evidently deposited from solution, and that mostly from above, for the ore bodies are superficial, while the mammalated and stalactitic structures tell their own tale. The nickel ore contains a little cobalt, seldom over 0·6% CoO. There was a reported find of nickel sulphide at Bourail some two years ago, and Mr. Moore had some small chips of yellowish nickel sulphide brought to him for determination, but on a careful personal investigation of the workings alleged to have furnished the samples submitted, I failed to find any trace of a sulphide of any kind, though the workings were not extensive, and were

still quite fresh. The minerals associated with these nickel ores, beside those constituting the rock, are chromite and asbolite in small quantities.

The nickel deposits are found between 400 and 4,000 ft. above the level of the sea, generally about 2,000 ft., the country rock being peridotite. The hills and valleys appear to have been mostly formed by anticlinal and synclinal curves, the latter having been deepened by river erosion, for the country is very well watered. Where cuttings intersect spurs that are not too much broken up by landslips, one can almost always see an anticlinal structure, the bands into which the peridotite is divided giving it almost a bedded appearance. The mountains are very steep and do not as a rule have much soil on them; what there is being very ferruginous and supporting but a scanty vegetation. The steepness of the mountains has helped in the formation of landslips, which are indicated by the profile of the spurs. This is interesting as certain of the landslips that have broken up the rock to the necessary degree are the sites of the most important nickel deposits, while the physical appearance of the surface acts as a guide to the prospector. In some places the ore crops out at the surface, at others it is covered with red earth in which pisolitic iron is found. In the latter case one may walk over the ground several times without finding any trace of nickel. The nickel is often leached out of the deposit at the surface, to be concentrated a few feet lower down. Pisolitic iron and a network of quartz veinlets are considered favorable signs for nickel deposits. What they really indicate is that the rock has been more or less broken up and decomposed, and therefore it is likely that the nickel originally in the rock has been concentrated in their neighborhood, though perhaps not showing on the surface. When the peridotite is decomposed under ordinary conditions, the magnesia appears to be the first ingredient to be carried away, in the form of carbonate; this is followed by nickel and quartz, which are deposited in the joints; the iron becomes oxidized and hydrated, and coming in contact with scarcely any solvent capable of acting on it, remains behind; furthermore, as it is heavy, when rains wash away the earth in which it is imbedded, the pieces of iron ore become concentrated on the surface. It is interesting to note that fresh undecomposed pieces of peridotite, consisting chiefly of olivine, contain nickel up to 1%, from which the occurrence of an extensive deposit would appear to prove that either there had been a large quantity of rock above it, now disintegrated, or else that the nickel had leached out from the higher lying ground. The deposits may be divided into two classes: (1) Those in which the ore is found in joints and slides in hard rock, and (2) those in which the rock is more or less decomposed, so that it has to be worked out in bulk. There can be no sharp division of the two classes unless extreme types are taken, though they undoubtedly exist with reference to origin, and decidedly affect the mining of the deposits.

In the former case (1) the joints are filled with rich green nickel that can be picked out from the rock which, for commercial purposes, is barren. Being rich, the expense of considerable dead work can be borne for the sake of the small quantity of ore won. This kind of stockwork is generally caused by the sharp bending of the rock, which causes tension joints to form without breaking the rock between into small pieces. The walls of the joints may be weathered

for an inch or two and this being nickel bearing, is "knapped" off. There are also fault planes 3 or 4 ft. wide, filled with rubbed up pieces of country rock cemented together with green nickel. These cementations were worked in the early days of nickel mining in New Caledonia when only the richest ore paid for its extraction.

At the present time the decomposed deposits (2) produce the greater bulk of the ore. It is mostly brown ore, and is poorer than the green nickel on account of being contaminated with so much decomposed rock. It generally accompanies a landslip which, in sliding down in a body, breaks up the ground in such a manner as to enable the rock to be readily weathered. There is a considerable green nickel in these deposits which evidently occupied the joints before the rock was so completely decomposed; possibly some of it was formed before the mass slipped down, when it may have constituted the harder deposit. Occasionally a hard bar of rock is found which for some reason has withstood the weathering action better than the rock surrounding it. It could not be determined whether the nickel was limited to any particular variety of peridotite, but it occurs most frequently in the more common sorts, probably because there was more of it rather than on account of any slight difference in the proportion of its mineral constituents. Sometimes these deposits end rather suddenly against rock, while at other times they get poorer gradually. They vary in size from 6 in. to 30 ft. in vertical depth. These differences may be due to the varying effects of weathering action on the rocks under different physical conditions, but very likely the shallow deposits are merely the remnants of larger ones, the bulk of which has been washed down the hillsides. Without considering any leached surface stone that may have to be removed, the part of the deposit nearest the surface is the richest portion, getting poorer as it enters the hill; the higher portion of the deposit is also richer than the lower, as if only the dregs of the nickel in solution escaped precipitation higher up and near the surface and found its way lower down the hill. Still, though the deposits are comparatively shallow, they cover large areas and there are deposits working now that have already produced from 30,000 to 100,000 tons of ore, which have every prospect of yielding as much again.

The method of mining is simple open cut work; the ore is taken out in benches having faces about 30 ft. high. The ore, after being blended to a shipping grade is sent to the low land on aërial ropeways and then conveyed to the coast on ground trams, from which it is transferred to lighters for conveyance to ships.

Chile.—During the latter part of 1901 shipments of cobalt ores were made from Caldera to the United Kingdom, and it is anticipated that the returns will show sufficient profit to render the re-opening of the mines advisable.

Mexico.—In the Mirador mine, in the State of Jalisco, an unusual occurrence of cobalt ore was discovered during 1901. The rock is a blue quartz, very hard and tough, showing some minute specks of pyrite. The analyses showed 98% SiO_2 from 0·42 to 0·55% Co, and from 0·40 to 0·50% Fe. The cobalt and iron are combined with sulphur, but apparently not associated with each other. Neither nickel nor copper could be determined in the ore.

Norway.—Experiments made on Norwegian nickel ores at Soetersdalen, at

the Osterōen works, near Bergen, and at the Foeö works near Hangesund, during the latter part of 1900, were successful, but little or nothing has been done to open the deposits owing to the lack of capital for the opening of the mines on a practical working scale.

Russia.—During the latter part of 1901 the discovery of rich deposits of white nickel and asbestos was reported from the neighborhood of Zanghésour, Province of Elizabethpol.

The Cobalt Ores of New Caledonia.

By F. Danvers Power.

The cobalt ore occurring in New Caledonia is cobaltiferous manganese oxide, and the output for 1901 amounted to 3,123 metric tons, as compared with 2,437 tons in 1900. Cobalt ores are generally found associated with nickel ores, but independent of the nickel deposits, though the cobalt ore carries from 1 to 2% NiO, and nickel ore from 0·1 to 0·2% CoO. The cobalt deposits are purely superficial and are mostly found on the mountains in a reddish earth formed by the decomposition of the peridotite. Miners seek for dark stains of manganese oxide, locally called "cobalt smoke," and depend on these to lead to something more tangible, or if they are in a cobalt district, they burrow at random into the earth in the hope of striking a body of ore. The peridotite has a band-like structure, which has become buckled into anticlinal and synclinal curves. The cobaltiferous manganese (probably obtained from the original rock, the residue of which now forms the large bodies of red earth) concentrated in the joints, especially those of the bed-like type, and in the parts that form the synclinal. These main joints are followed by the miners until too small to be profitable. The cobalt ore was evidently deposited in the joints before the rock was completely decomposed, for the ore can be traced in the joints from the slightly decomposed rock into red earth, and also into the rock structure until it is obliterated by the apparently uniform mass of earth. When two or more joints meet, a pocket of ore may occur. The cobalt ore in the solid rock can be picked out by hand, but in the red earth it is often broken up, and so mixed with worthless material that it requires to be cleaned by weathering and washing. The red earth being soft is readily washed away by rain and small streams of water, and the prospector is aided in his work by exposing the deposits to atmospheric agencies, preferably driving a tunnel rather than sinking a shaft.

The mining is generally carried out in a very primitive and erratic manner, but the principle on which the larger mines are worked is to follow a more or less horizontal body of cobaltiferous manganese into a hill by means of a tunnel as far as it will pay; about every 30 ft. in distance branch drives are put in at right angles to the main one, in order to discover the lateral payable limits of the ore. When these are found the ore is blocked out from the far end and the ground allowed to fall in behind. The drives are most irregular in direction and grade and there seems to be no systematic prospecting done to determine how many veins of ore there are to be mined and the best way to win them at the least possible loss.

The dressed cobalt ores, which assay from 3 to 8% CoO, are blended to form

the shipping grade of from 4·75 to 5% CoO. The cleansing of the ore also is very primitive. In the mine the ore is kept as clean as possible from the earth, but there is always a certain proportion that cannot be separated by hand picking. Ore of this character is sometimes allowed to weather for a few days and is then sent down in bags to a creek, where it is crushed by hand with a big wooden pestle and washed in a sluice box by shoveling the material against the down-flowing stream of water. In this way the ore as mined is concentrated from 3 to 9 parts into 1.

It is interesting to note that the cobalt ore at Port Macquarie, in New South Wales, is of a similar nature to the deposits in New Caledonia—the ore occurs in the joints of altered peridodite and serpentine, more especially in the trough folds. At Port Macquerie, however, there is less red earth than in New Caledonia and the deposits are not at so high an elevation above the sea level.

Progress in the Metallurgy of Nickel during 1901.

By Titus Ulke.

The Lake Superior Power Co.—This company has completed the first set of 16 Herreshoff roasting furnaces at Sault Ste. Marie, with which it is proposed to roast dead 50 tons per day of finely crushed ore from Sudbury mines, and pyrites from Michipicoten. The furnaces are fired by producer gas and the sulphurous acid gas produced is utilized for the treatment of wood pulp by the sulphite process and for making liquid sulphurous acid. At present the roasted ore is briquetted in a Boyd & White press and stored for future use. It has been proposed to manufacture ferronickel from the roasted ore, but its copper content is believed to be too high for this purpose. The company has blown in one and is erecting two more elliptical water-jacketed furnaces near its Gertrude mine on the Manitoulin & North Shore Railroad for treating the heap-roasted nickel-copper ore from the Elise and Gertrude mines. Two stands each of three trough converters, furnished by Fraser & Chalmers, are to be placed on the terrace below the smelting furnaces for converting the daily output of about 40 tons of nickel-copper matte.

The Lake Superior Power Co.'s method of handling ore to and from the roast-heaps by locomotive, side-dumping cars and steam-shovel is excellent, and is far more economieal than the prevailing method of hand-wheeling and shoveling adopted by the Canadian Copper and Orford companies.

The Canadian Copper Co.—Among the improvements introduced at the smelting works of the Canadian Copper Co., at Copper Cliff, is the efficient flue-dust chambers with which the new water-jacketed elliptical furnaces are supplied. It has also been profitable to replace a certain proportion of the roasted charge in smelting by "green" (*i.e.*, unroasted) ore, although a low-grade matte is thereby produced. The Canadian Copper Co. operates about 80 roast-heaps and 9 furnaces which smelt approximately 900 tons of ore per day. Twelve hundred men are employed at an average wage of nearly $2 per day. The ores average about 2% Cu and 2% Ni, although the Creighton mine supplies ore that averages about 5% Ni and quite low in copper. The cost of roasting at Sudbury has been estimated not to exceed 17c. per ton of ore and the cost per pound of nickel con-

tained in the matte lies between 7·2 and 7·8c. At the beginning of the year 1902, the average composition of the matte produced by the Canadian Copper Co. was about 13·2% Cu, 17·8% Ni, 0·45% Co (=2·5% of the nickel present), 42·0% Fe and 21·4% S. Besides these elements it contains about 1·90 oz. silver, 0·35 oz. platinum and 0·35 oz. palladium per ton, or a total value per ton in precious metals of about $13·50. The slag produced at Sudbury varies between 27% and

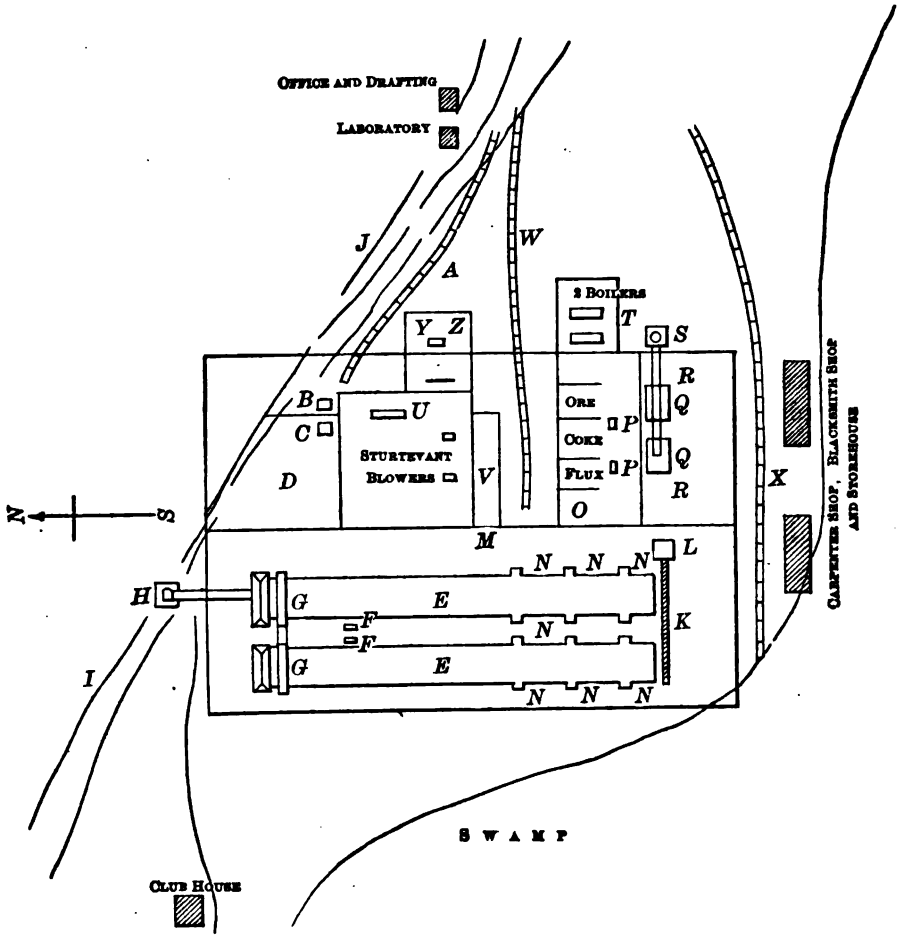


FIG. 1.—THE WORKS OF THE CANADIAN COPPER CO., AT COPPER CLIFF.

38% SiO_2, 43 and 46% FeO, and contains about 4·5% CaO, 2·5% MgO, 10·0% Al_2O_3, 2·0% S, 0·3 to 0·4% Cu and 0·3 to 0·4% Ni.

The Ludwig Mond Co.—The plant of the Ludwig Mond Co., at Victoria, 22 miles west of Sudbury, was completed early in the year and smelting commenced in May, 1901. The nickel and copper ores are heap-roasted, smelted to matte and Bessemerized to a metallic content of 80% nickel and copper. The ore mined by this company in 1901 amounted to 46,807 short tons, of which 18,628 tons were smelted and produced 1,147 tons of matte containing 462 tons of copper and 455 tons of nickel. This matte was shipped to England. Since beginning operations

the type of the charging thimble has been reduced to 18 in., which permits of a better distribution of the charge in feeding the furnace. The walls of the settler have been increased in thickness to the extent of an additional width of fire brick, which has resulted in prolonging the life of the settler. The granulation of the matte has been discarded on account of the difficulty encountered from the numerous violent explosions. The following charges were recently made to the furnace: From 1,500 to 1,800 lb. roasted ore, from 400 to 750 lb. of low-grade siliceous ores, called "rock," and from 0 to 600 lb. converter slag. Each charge weighed about 2,500 lb. and required 300 lb. of coke for its reduction. Occasionally green ore is added and at times a portion of the matte is resmelted. During 24 hours the converters produced 44 plates, or 11 tons of 80% matte, which is a very large output considering that only one matting furnace under a blast pressure of 3 oz. was in commission. This furnace treated 150 tons of material in 24 hours, an amount which could be easily increased by raising the blast pressure. The blast is preheated by leading the air from the blowers into a passage way, built above the dust flue and separated from it by a steel diaphragm, thus utilizing the heat of the waste furnace gases. The air enters near the chimney to which the flue leads and proceeds toward the furnaces where the furnace gases have the highest temperature. The dust flue is constructed of steel plates lined with fire brick and is 160 ft. long, 9·5 ft. wide and 11 ft. high, including the air passage way, which is 24 in. high at its center. (See Fig. 1.) The weight of the flue in the smelter building is carried by the steel beams of the charging floor. It is estimated that from 400 to 500 tons of ore can be smelted daily in two 44×120 in. water-jacketed copper furnaces. Each furnace is provided with 8 tuyeres on a side, placed 15 in. between centers, and with a steel water jacket 8 ft. in height. A 6-in. water space is allowed between the inner and the outer walls of the jackets, which are of 0·375 in. and 0·3125 in. thickness, respectively. The side jackets are 5 ft. wide and the end jackets 4 ft. wide. The furnace is 18·5 ft. in height from the ground to the charging floor and the charging opening is 7×2 ft. in size. The centers of the tuyeres are on a level 5 ft. 8 in. above the floor. The crucible is 22 in. in height from base plate to water jacket and is supported on a thick iron plate resting on 12 cast-iron columns 3 ft. 1 in. in height. Above the jackets, vertical brick walls 9 in. thick are carried a distance of 5 ft. 3 in. to the charging floor. The inner dimensions of the furnace at the tuyere level are 3 ft. 8 in.×10 ft. and at the top of the jacket, 5 ft. 8 in.×10 ft. The slag and matte produced in these furnaces are run into a settler or forehearth and there separated by gravity and periodically tapped. The forehearth is 9 ft. in outside diameter and 3 ft. 6 in. in height. It is supported on 45-lb. rails, riveted to the bottom, the rails resting on rollers 2 in. in diameter and 2 ft. 6 in. long, so that the top of the fore-hearth is 4 ft. above the floor level. The lining is enclosed in a shell of tank steel 0·1875 in. thick at the sides, and 0·25 in. thick at the bottom, respectively, stiffened by 2·5×2·5×0·5 in. angles. To the half covers of the forehearth are riveted 30-lb. rails and 3×3×0·5 in. angles, two lifting handles being attached to the latter. The forehearth has a copper spout and a copper tapping jacket 2 ft. wide by 2 ft. high and 4 in. thick at the tap hole, containing several sections of 1-in.

wrought iron pipe cast in the piece. A guide 18 in. wide and 11·5 in. high is bolted to the forehearth and supports the copper spout which is 13 in. long, 6 in. wide, 4·5 in. high and 1 in. thick, with a flange 11·75 in. wide and 8 in. high. At present the slag flowing from the settler is wheeled to the dump and poured, but eventually it may be granulated and carried to a pit, from which it can easily be lifted by an endless chain and buckets to a bin and loaded in the cars. The matte accumulating in the settlers is periodically tapped into movable launders and run into the two 6-ton converters. The plant is equipped with six converter shells and two stands. The converters are of the horizontal type and measure 6 ft. 8 in. in diameter and 7 ft. in length. They rest on roller wheels supported by a strong cast-iron frame and are revolved by a vertical rack bar extended downward into an hydraulic cylinder and geared with a toothed wheel attached to the converter. The wind-box, 6 ft. long and 1 ft. high, is bolted to the converter and supplies the blast through 11 tuyeres on one level. The Bessemerized matte from nickeliferous copper is poured into a ladle suspended from an overhead traveling crane and is cast direct into plates. Ordinary clay from the neighborhood of the plant is used as a binder with the crushed quartz for lining the converter. The newly lined converters are dried by burning a few sticks of wood with a slight blast inside. The converting of the nickel-copper matte is now carried on as follows: The ordinary matte, averaging between 30 and 50% Ni+Cu and varying in composition with the grade of the material fed to the smelting furnace, is tapped from the settler and run into the converter so as to fill it nearly to the level of the spout in the charging position. During the next 30 to 45 minutes the tuyeres are occasionally opened by inserting a cleaning bar, and finally the converter is tilted and the first slag skimmed. As soon as matte begins to show, (determined by peculiar spots appearing on an iron rod held in the slag stream) the converter is turned up and the second stage of converting commences, which usually lasts about 40 minutes. During this time the iron is almost completely removed and a few additional pots of slag may be skimmed off. The operation is continued until the slag foams or becomes granular and the proper finishing flame appears, accompanied by the right "action of the converter," as determined by the man in charge. The Bessemerized matte, if sufficient in quantity, is then poured into a ladle suspended from a traveling crane to be cast into shallow plates, or, if small in amount, it is allowed to remain in the converter, and an additional quantity of ordinary matte is tapped from the settler and run into the converter, and the operation repeated. In this manner two or three tappings of ordinary matte are run into the converter before the charge is finished and enough Bessemerized matte accumulated to make nine or ten plates, each weighing about 500 lb. In these cases three to four hours may elapse between the first charging of the converter and pouring of the finished matte. Occasionally it is necessary to transfer the charge from one converter to another because of the dangerous thinning down or burning through of the converter lining. The converters are said to stand from 4 to 8 charges of matte before they require complete relining.

According to Mr. Paris, of the Mond Co., a typical analysis of the granulated converter slag was SiO_2, 49%; Cu, 4%; Ni, 18·6%; and Fe, 16·9%. Ordi-

nary converter slag averages about 1·5% Cu and from 1·5 to 2% Ni, and is returned to the blast furnace feed-floor to be added to the smelting charge. For good practice the converter hoods should be built 18 in. higher than those in the Mond works, in order to restrict the spattering of portions of the charge; and each of the rails attached to the converter body should be in two sections instead of one, the joint being placed for greater convenience in handling at the junction of the hood and the converter body.

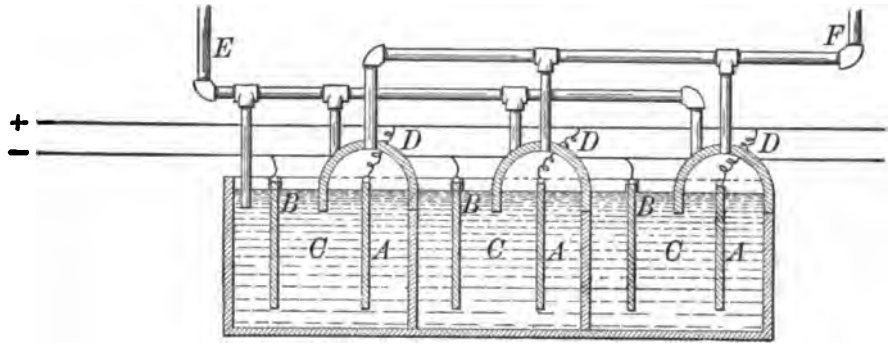
The composition of the Bessemerized matte produced at Victoria is about as follows: Ni, 37·78%; Cu, 41·4%; Fe, 0·65%; S, 18·37%; and SiO_2, 0·19%.

The Orford Copper Co.—During 1900 the Orford Copper Co. erected a plant at Copper Cliff to treat the nickel-copper matte furnished by the Canadian Copper Co. The matte is roasted in Brown straight-line calciners and smelted in an Orford cupola furnace to a matte containing 80% of Ni+Cu, which is shipped to the Orford works for treatment. The following description of the new plant was kindly furnished by Mr. J. A. Robert: The equipment consists of a 75-H.P. engine, two 125-H.P. boilers, dynamo, Cameron pump, Krupp ball mill, Blake crusher, two Brown straight-line calcining furnaces and two cupola smelting furnaces as outlined in the plan given in Fig. 1. The copper-nickel matte is at *B;* thence through a spout to the 50-ton Krupp mill at *C,* after which it falls delivered from cars at *A* and fed to the hopper of the 16×20 in. Blake crusher to the floor at *D.* At present the fine material is taken in barrels to the hoppers of the calciners *EE,* but later it is intended to use a conveyor to carry this material to storage bins located above the hoppers. The calcining furnaces are fed automatically and each treats 40 tons per day. The roasted matte containing from 8 to 10% S is received at the end of the roasting furnace in a screw conveyor *V* and is spouted to the boot of the bucket elevator *L* and lifted to the bin *O* of the two Orford smelting furnaces *QQ,* adjacent to the bins for ore and coke. In front of the bins are two small platform scales *PP* for weighing the charges. There are two boilers at *T* and an engine house *U* with two Sturtevant blowers to furnish blast for the furnaces. A small electric plant *Z* will supply arc lights to light the works with and will furnish current for use in the laboratory. *W* and *X* are railroad tracks for handling material to and from the works. Coal is received in bins at *V* and falls by gravity through a door at *M* in front of the fireboxes *NNN* of the calciners *EE.* The carpenter shop, blacksmith shop and storehouses are located along the track *X* on the lower level. The office, laboratory, drafting room and club house are on the higher levels near the works. Each Orford furnace is of 100 tons daily capacity, and the dust flues *RR,* one over the other, lead from the furnace to the stack *S.* It is intended to produce a finished matte of 80% Ni+Cu which will be received from the spout of the cupolas on a patented conveyor not yet put in place. Chalcopyrite ore, high in silica, from the Massey mine is to be used in the cupolas with calcined matte. The plant is located on the side of a steep hill, the crusher at *B* being 25 ft. above the floor of the calciners. The crushers, calciners and furnaces occupy a space 180×160 ft. under one roof and the plant is planned to handle materials as cheaply as possible by utilizing gravity.

Shuler's Process of Treating Sudbury Ores.—Dr. Shuler has proposed the

use of magnetic separators to remove the iron and nickel minerals from the Sudbury ores which, he believes, will yield a nickel ore containing as little as from 0·1 to 0·2% Cu, an amount too small to interfere with the finished steel made from these ores. The nickel portion, which carries most of the iron and sulphur, is dead roasted, briquetted and smelted into nickeliferous pig iron in an iron blast furnace. As the Sudbury ores carry but little phosphorus and as most of this is removed by the magnetic separation, the resultant pig iron will be very low in phosphorus, 0·03% P or less. (United States Patent No. 697,370 of April 8, 1902.)

Browne's Electrolytic Process for Depositing Nickel.—It is understood that for some months a plant near Cleveland, O., has been producing from 8 to 15 tons of nickel per month, operating under a Canadian patent of David H. Browne.[1] This electrolytic process consists of the following steps: Anodes of copper-nickel alloy and cathodes of pure copper are suspended in a solution of copper-nickel chlorides which is continuously regenerated by passing it through



A. Anodes. *B.* Cathodes. *C.* Electrolytic. *D.* Water-sealed anode cell. *E.* Pipe from ammonia tanks. *F.* Pipe conveying chlorine gas to tower.

FIG. 2.—BROWNE'S ELECTROLYTIC PROCESS FOR THE ELECTROLYTIC SEPARATION OF NICKEL AND COPPER.

a tower filled with Bessemerized matte or alloy to be treated, in contact with salt solution and chlorine gas evolved from the nickel precipitating process. When the electrolyte is rich in nickel, and the copper nearly all deposited on the copper cathode, the remaining copper and the iron are precipitated therefrom in turn by hydrogen sulphide or a similar reagent, and I am informed, ammonia, and the nickel chloride solution electrolyzed in contact with carbon anodes in a water-sealed compartment (see Fig. 2) and pure sheet nickel cathodes. The chlorine evolved from the anode compartment is conveyed to the regenerating tower.

Ulke's Continuous Electrolytic Process for Separating Nickel and Copper.—With the Ulke process it is most advantageous to use a material consisting of not over 20% Ni and not less than 80% Cu, which is cast into anode plates. The electrolyte consists of a solution of copper and nickel sulphate, and contains an excess of free sulphuric acid,—and the cathodes are of pure sheet copper. The electrolyte is heated and kept in circulation, and from time to time portions of it

[1] No. 74,401 of Jan. 14, 1902, reissue of No. 69,729 of Dec. 21, 1900.

are withdrawn from the electrolytic vats to be re-standardized. The following rule is observed in withdrawals: If, for example, the anode contains 10% Ni and is completely dissolved in 10 days, and if the percentage of nickel in the electrolyte is maintained at 4%, it is found that about 3% of the total volume of solution in circulation should be withdrawn daily. The electrolyte withdrawn is replaced with an equal volume of copper sulphate solution, containing an excess of sulphuric acid, to re-standardize the electrolyte. A portion of this copper sulphate is obtained as a by-product in the extraction of the nickel as is outlined later in this description. While the withdrawn electrolyte may be treated with ammonium sulphate to precipitate the copper, and the filtrate refrigerated to obtain the double nickel-ammonium sulphate, it is preferable to effect the separation by a cyclic process in which the copper is precipitated with hydrogen sulphide, and after filtering, the copper sulphide precipitate is treated by heat and sulphuric acid to recover the hydrogen sulphide and to make the by-product copper sulphate. The nickel sulphate is made ammoniacal, and used hot as an electrolyte for the precipitation of the nickel, using anodes of lead and cathodes of sheet nickel. To avoid impoverishment of this electrolyte, portions of it are periodically withdrawn, the ammonia recovered for re-use and the nickel sulphate added to the electrolyte as needed to preserve the proper strength. This process is economical, and produces nickel of high quality continuously and cheaply.

Deposition of Tough Sheet Nickel.—Dr. Moritz Kugel, of Berlin, has obtained a patent[2] for the production of a tough, flexible and extensible sheet of nickel of homogeneous non-crystalline structure, and of any required thickness, which is made by subjecting a solution of nickel salts to an electric current at a temperature of 30°C. and upward, this electrolyte being kept acid by continuous additions of a non-electrolyzable acid such as per-chloric, per-bromic, or sulphuric acid.

Electrochemical Behavior of Nickel Ammonium Sulphate.—W. Pfanhäuser[3] states his conclusions with reference to the electrolysis of nickel ammonium sulphate solutions: 1. Nickel-ammonium sulphate has a greater specific electric conductivity than nickel sulphate. 2. In complex solutions the double salt dissociates completely, while in dilute solutions it is proportionate to the concentration, being partial or complete. Therefore if the electrolyte is not circulated mechanically, the complex salt will be simultaneously decomposed at the cathode and re-formed and crystallized at the anode. 3. At the anode, an oxidation of nickelous to nickelic sulphate takes place continuously, and, by hydrolytic dissociation, a deposit of nickel hydroxide is deposited on the anode, unless an excess of sulphuric acid be present which reduces the nickelic sulphate to nickelous sulphate, sulphuric acid, and oxygen. 4. As long as the operation is conducted with normal low current densities, the separation of nickel on the cathode is of a purely secondary character. With higher current densities the solution near the cathode is depleted of metallic constituents more rapidly than these are replaced by diffusion, the complex salt being decomposed into nickel and ammonium sulphates, which carry the current. Whenever nickel sulphate acts as a

[2] United States Patent No. 665,915, January, 1901.

[3] *Zeitschrift fuer Electrochemie*, 1901, 7 (50), pp. 698–710.

current carrier, a primary deposition of nickel occurs, which increases with the further dilution of the electrolyte near the cathode. Since a primary deposition of nickel is powdered and black, dilute solutions and high current densities are to be avoided. 5. By circulating, stirring or heating the electrolyte, the differences of concentration are equalized, and a higher cathode current density may be employed. Whenever the electrolyte contains a metallic salt capable of different stages of oxidation, a counter electromotive force is produced which varies with different metals as anodes, according to the difference in the rise of potential, between the anodes and the normal electrolyte.

Electrolytic Separation of Cobalt from Nickel.—D. Balachowsky[4] suggests the separation of cobalt from an acetic acid solution of the metals, to which has been added for each 0·3 g. of metal, 3 g. of ammonium thiocyanate, 1 g. of urea, and from 1 to 2 c.c. of ammonia to neutralize the excess of acetic acid, the whole being diluted to 100 c.c. A maximum E.M.F. of 1 volt, and a minimum current density of 0·8 amperes is employed, at a temperature of from 70 to 80°C. The cobalt is retained in solution while the deposited nickel is dissolved from the cathode by nitric acid and the solution filtered to remove the sulphur from the nickel sulphide plated on the cathode, and electrolytically treated in the presence of ammonia. The cobalt solution is evaporated, acidified with nitric acid, filtered, ammoniated and electrolyzed. Cobalt is extensively used in Europe for the production of a bright purple dye. In America, at the American Nickel Works, Camden, N. J., cobalt oxide is prepared from cobalt ores from Mine la Motte, Mo.

Nickel Alloys.—Nickel aluminum sheet is now made commercially with a tensile strength of 40,000 lb. per sq. in., and an elastic limit of 25,000 lb. per sq. in. Its price is the same as for aluminum sheets of the same size and thickness. Various alloys of aluminum and nickel are described elsewhere in this volume in the section devoted to aluminum.

Ferro-nickel, containing 25, 35, 50, and 75% nickel respectively, and analyzing about 1% C, 0·3% Si, 0·02% S, and 0·03% P, is manufactured in large quantities so that the percentage of nickel required in steel may be absolutely controlled. The ferro-nickel is malleable and homogeneous and may be readily rolled or drawn.

Chrome-nickel containing usually 73% Cr, 23% Ni, 2·5% Fe, 1% C, and 0·5% Si, is used in making a high-grade steel containing fixed percentages of chromium and nickel, to be utilized in the manufacture of armor plate and projectiles. Plates made by this process are said, when tempered, to be superior to Harveyized steel armor-plates.

Tungsten-nickel is now supplied by several firms, for steel manufacture, of a general composition of 23% Ni, 73% W, 2·5% Fe, 1% C, and 0·5% S.

Molybdenum-nickel alloy may be obtained in a fused state, instead of the powder commonly produced. Its composition ranges from 45 to 75% Mo, 20 to 50% Ni, 2 to 2·5% Fe, 1 to 1·5% C, and 0·25 to 0·5% S. The use of molybdenum in powdered form led to an irregular product caused by the losses of molybdenum by oxidation, and the substitution of a fused alloy, is said to insure an absolutely uniform product, containing a percentage of molybdenum

[4] *Comptes Rendus*, 162 (24), 1492–1495.

which is variable at will. As molybdenum containing from 95 to 98% Mo, is difficultly fusible, and consequently hard to alloy with steel, it is first alloyed with nickel, and largely used in the manufacture of forgings, guns, wire, boiler-plate, and shells.

Nickel Steel.—Both metallic nickel and nickel oxide are used by the Bethlehem and Homestead works for making nickel steel. The Orford product at present contains about 99·21% Ni and 0·13% Cu.

Electrolytic Manufacture of Nickel Forms Direct from Solutions.—Deposits of nickel capable of being rolled or hammered are now manufactured with entire feasibility.[5] Owing to the necessity for the use of a hot electrolyte to effect the deposition, wax or fusible matrices are inapplicable. Fusible metal cores alloy with the deposited metal to such extent that it is impossible to obtain clear and brilliant surfaces. Collapsible molds are expensive and difficult to construct. A matrix recently patented by Carl Steinweg, of Ludensheid, Westphalia, apparently solves the problem: The matrix is formed of a metal or alloy of low tensile strength such as lead, and has an external face which is smooth on which the metal is electro-deposited. Its inner surface is grooved so that the sections between the grooves may be readily stripped from the interior of the finished article. A recent patent[6] of Messrs. Kugel and Steinweg seems to offer a practical way for avoiding irregular deposition on the cathode, on account of the shape of the article to be manufactured. A perforated anode exactly corresponding to the shape of the article desired to be produced is constructed hollow of glass or ebonite, and hung in the electrolyte above the cathode. The hollow anode is filled with filings or cuttings of the metal to be deposited at the cathode. Strips of the same metal are buried in the mass of filings to serve as conductors, and as the electrolyte but slowly permeates the mass they are not quickly destroyed. As the anode and cathode so perfectly correspond in their adjacent surfaces, the distance between them may be reduced to a minimum, with consequent reduction of the resistance, an advantage in working which is not practicable with present methods.

[5] *Electrical World and Engineer*, March 15, 1902. [6] German Patent No. 113,871 of 1900.

OCHER AND IRON OXIDE PIGMENTS.

THE production of all mineral paints, including ocher, umber, sienna and iron oxide in 1901 was 43,036 short tons, valued at $516,306, as compared with 41,917 short tons, valued nominally at $461,087 in 1900, while the imports of these products were respectively 11,149,274 and 10,974,544 lb. The production of Venetian and Indian reds in 1901 was 9,201 short tons, valued at $153,467, as compared with 6,352 short tons, valued at $110,658 in 1900. The leading States in the production of ocher are Pennsylvania, Georgia, California and Vermont, while iron oxide comes largely from New York, Pennsylvania and Tennessee. Umber and sienna are produced chiefly in Illinois and Pennsylvania. Under Venetian and Indian red is included only the pigment made by calcination of copperas. The chief producers are the American Steel & Wire Co., at Waukegan, Ill., and Worcester, Mass.; C. K. Williams & Co., Allentown, Pa.; S. P. Wetherill & Co., Philadelphia, Pa.; and Mepham & Klein, St. Louis, Mo.

IMPORTS OF OCHER, UMBER AND SIENNA INTO THE UNITED STATES.

Year.	Ocher of All Kinds.						Umber. (b)		Sienna.			
	Dry.		Ground in Oil.		Total.				Dry.		Ground in Oil.	
	Pounds.	Value.	Pounds	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds	Value.
1897	a 7,720,075	$59,272	20,123	$1,000	7,740,198	$60,272	1,447,889	$14,479	580,468	$12,340	7,058	$481
1898	5,898,720	46,571	31,460	1,546	5,930,180	48,117	1,123,079	9,051	544,713	11,451	4,008	280
1899	9,765,616	72,825	14,881	756	9,780,497	73,581	1,739,036	13,336	758,691	14,242	6,484	492
1900	8,449,252	57,342	19,167	1,019	8,468,419	58,361	1,702,256	11,862	796,534	14,912	6,395	495
1901	8,546,691	88,196	16,738	918	8,563,429	84,114	1,465,431	12,510	1,106,553	18,294	13,861	1,004

(a) Includes 241,452 lb. entered as crude and 1,416,587 lb. as powdered. (b) In 1897 includes 14,471 lb. ground in oil and 1,433,418 lb. dry, crude or powdered; in 1898, 4,608 lb. ($333) ground in oil and 1,118,471 lb. ($8,718) crude, powdered, washed or pulverized; in 1899, 4,849 lb. ($300) ground in oil and 1,734,187 lb. ($13,036) dry, crude, powdered, washed or pulverized; in 1900, 11,653 lb. ($723) ground in oil, and 1,691,603 lb. ($11,139) dry, crude, powdered, washed or pulverized; in 1901, 3,184 lb. ($173) ground in oil and 1,562,248 lb. ($12,337) dry, crude, powdered, washed or pulverized.

Iron oxides and Venetian red are produced from natural and artificial sources, principally the latter in connection with the manufacture of copperas, which is made as a by-product from the spent vitriol used in cleaning wire and wire rods. The bottom crystallization of copperas is too impure to be disposed of in a commercial way and, as its use is limited, the greater part of it is converted by different processes into iron oxides.

The principal method of manufacture is called the "dry process," in which the copperas is roasted in a furnace with an admixture of lime or similar material to neutralize the acid in the sulphate, until the required strength and color are obtained. This method is considered the cheapest and quickest for the production of low grades of oxides. Copperas alone is roasted a sufficient length

of time until only the pure oxide remains, which is then reduced with the aid of a filler, as whiting, to form the different grades of Venetian red. Samples of this product sometimes have as little as 10% of iron oxide or coloring power. The dry process varies in details of furnace arrangement, crucibles, application of heat, etc.

There is also in use a "wet process," which is more economical, although the product is not as uniform as that produced by the dry process. By the wet process, the waste pickling liquor is treated direct for its iron content. Several patents have been applied for on the principle of passing steam direct to the waste acid solution for the purpose of oxidation, while in others, milk of lime, sodium carbonate, or other precipitant, is added to the waste liquor to precipitate the iron as a hydrate or carbonate, which is collected at the bottom of the tank and subsequently separated by passing the liquor and precipitate through filter presses, where all moisture is removed. The press cakes are roasted in furnaces, cooled and packed for the market without grinding. The product is of medium strength, not uniform, and can only be used for limited purposes. Apart from the above-mentioned methods, different colors and strength of oxides are produced by the addition of natural ores and ochers. Furthermore, iron ores in different parts of the country are also ground and sold direct as Venetian reds. The strength, color and fineness of natural reds, however, are inferior to the manufactured article and do not command as high a price. Considerable improvement has been made in the domestic product during recent years, and importations are decreasing. It is probable that nearly the entire domestic demand for high and low-grade iron oxides will be filled in the United States in the near future.

The principal manufacturers of iron oxides and Venetian red are: the American Steel & Wire Co., at Worcester, Mass., and Waukegan, Ill.; C. K. Williams & Co., Easton, Pa.; S. P. Wetherill & Co., Philadelphia, Pa.; Henry Erwin, Bethlehem, Pa.; Mepham & Klein, St. Louis, Mo.; and Hanna & Andrus Co., Chicago, Ill. There are also smaller producers in the country who devote their attention to the mined and natural reds only.

Market.—Prices in New York during 1901 averaged about $13 per ton in barrels for the mined reds, some of those mined in Maryland and the South being offered at $10. For the manufactured or copperas reds, prices averaged about $22 per ton, while for the iron oxide red considerably higher prices were obtained, depending entirely upon the strength of iron and color. None of the domestic producers report having operated its works to its full capacity for any length of time on acount of the production being in excess of the demand. It is also claimed that this business could not be operated profitably alone, but must be run in connection with another industry or as a means of disposing of waste material. There is but little opportunity for the development of export business as foreign mills manufacture iron oxides as a by-product besides producing natural reds and ochers.

Venetian reds and iron oxides are used principally where a low priced paint of durability is required, as for railroad, bridge and car work, roof and building paints, or as a preservative of iron. These paints are also used considerably in paper mills for sheathing-in color paper and in the manufacture of leather board.

PETROLEUM.

By F. H. Oliphant.

A conspicuous feature in the world's production of petroleum for 1901 was the remarkable increase in the supply of the lower grades, and the gradual decline of the higher grades of mineral oil in the fields of the United States. The discovery of new sources of petroleum supply in the Southwest has greatly extended the area of our fuel oil territory, while the fields from which is obtained the more valuable illuminating and paraffine products, are slowly but surely becoming exhausted, and new territory is absolutely necessary in order to sustain the present annual output. The consumption of petroleum for fuel purposes is assuming very large proportions, and both Russia and the United States have greatly increased their output of this quality of petroleum. The lighter products are likewise finding more extensive use as illuminants and for motor purposes. A large demand has also been created for them as a gas oil. Several large refineries are now in course of construction near Philadelphia, which will manufacture an oil exclusively for gas purposes, from the inferior crude product of the Gulf petroleum fields—the residuum finding a market as a high test fuel oil.

PRODUCTION OF CRUDE PETROLEUM IN THE UNITED STATES. (BARRELS OF 42 GAL.)

Year.	Appalachian Field. (a)	California. (b)	Colorado.	Indiana. (Lima Field.) (c)	Kansas.	Ohio. (Lima Field.)	Texas. (e)	Wyoming.	Other States.	Total.
1897.....	35,249,700	1,911,569	650,000	4,353,138	(c)90,000	16,507,000	65,000	15,000	(d) 9,000	60,849,407
1898.....	31,625,360	2,249,088	650,000	3,751,307	88,000	16,578,000	544,620	3,500	(d) 10,000	55,499,875
1899.....	62,870,689	2,677,875	600,000	3,818,713	(c)69,556	16,565,092	601,308	6,071	(d) 25,000	87,234,304
1900.....	35,540,965	4,250,000	525,000	4,329,950	(d)65,000	16,407,704	800,000	7,200	(d) 30,000	62,538,544
1901.....	33,618,180	8,786,330	460,520	5,757,086	179,150	16,176,293	4,393,660	5,400	12,623	69,389,194

(a) Includes New York, Pennsylvania, West Virginia, and part of Ohio. The statistics of production in this field and the Lima field in Ohio as given in previous volumes of The Mineral Industry were based on the pipeline receipts reported by the *Oil City Derrick*. They have been changed in the present volume so as to represent the actual production. (b) Statistics of California State Mining Bureau. (c) Statistics of State Geological Survey. (d) Estimated. (e) The statistics for 1899 and 1900 were furnished by Mr. C. F. Z. Caracristi.

Natural gas has become an indispensable agent in the economical operation of oil wells in the older portions of the producing region. The application of the gas engine to pumping oil wells has greatly cheapened the cost of production, and made it possible to operate the smallest wells at a profit. A failure of the natural gas supply in the oil country would result in the immediate abandonment of thousands of oil wells with a great decrease in the production and an increase in the cost of bringing the crude petroleum to the surface.

The following table gives a careful estimate of the quantity of petroleum produced in the world in 1900 and 1901 by countries. There are a number of countries that produce petroleum to a small extent, from which it has so far been impossible to secure any reports, because the business is carried on in the most primitive manner.

PRODUCTION OF CRUDE PETROLEUM IN THE COUNTRIES OF THE WORLD. (*a*) (IN METRIC TONS.)

Year.	Austria.	Hungary.	Canada.	Germany	India.	Italy.	Japan.	Russia.	United States.
1896.....	292,356	2,168	101,682	20,395	60,228	2,594	(*b*)81,314	7,105,768	8,502,187
1897.....	275,204	2,299	99,310	23,908	76,854	1,982	42,184	7,831,254	8,513,140
1898.....	323,142	2,471	98,044	25,789	71,627	2,015	(*c*)59,980	7,841,671	7,764,713
1899.....	309,590	2,125	113,718	27,027	106,000	2,242	(*c*)100,882	8,470,925	7,926,400
1900.....	347,213	2,199	91,139	50,464	140,084	1,683	64,508	10,524,919	8,262,406

(*a*) From the official reports of the respective countries. This table is only partially complete since it does not include the production of Roumania, Sumatra, Borneo, Java, South Africa, Peru, and some other countries. (*b*) Estimated from hectoliters. (*c*) Crude oil.

Petroleum is known to be produced and used to some extent in China, Persia, Turkey, and several of the South American countries besides Peru.

A general idea of the stocks on hand at the end of the year in the different districts may be gained from the following table in which the amounts are expressed in barrels of 42 gal.:—

Appalachian.				Lima.			
1898.	1899.	1900.	1901.	1898.	1899.	1900.	1901.
11,541,753	13,451,191	13,147,717	9,635,492	15,180,893	10,345,927	14,988,928	17,760,306

The average prices of petroleum in the Appalachian and Lima fields are given below:—

MONTHLY AND YEARLY AVERAGE PRICE OF PIPE-LINE CERTIFICATES PER BARREL OF CRUDE PETROLEUM AT THE WELLS IN THE APPALACHIAN FIELD.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly Aver'ge
1897...	$0·88	$0·90½	$0·92½	$0·85½	$0·85½	$0·86½	$0·76½	$0·71	$0·69½	$0·67½	$0·65	$0·65	$0·78½
1898...	0·65	0·67½	0·78½	0·79½	0·82½	0·87½	0·93½	0·97½	1·01½	1·18½	1·16½	1·17½	0·91½
1899...	1·17	1·15	1·13	1·13	1·13	1·13½	1·22½	1·27½	1·44½	1·50½	1·57½	1·65½	1·29½
1900...	1·66½	1·68	1·66	1·55	1·39½	1·25½	1·25½	1·25½	1·23	1·10½	1·06½	1·06½	1·35½
1901...	1·69½	1·25	1·29	1·20½	1·07½	1·05	1·13½	1·25	1·25½	1·30	1·30	1·21	1·21

AVERAGE MONTHLY PRICES OF CRUDE OIL IN THE LIMA FIELDS. (*a*)

Month.	1898.			1899.			1900.			1901.		
	North Lima.	South Lima.	Indiana	North Lima.	South Lima.	Indiana	North Lima.	South Lima.	Indiana	North Lima.	South Lima.	Indiana
January..	$0·46	$0·41	$0·41	$0·80	$0·75	$0·75	$1·19¾	$1·14¾	$1·14¾	$0·87¼	$0·82¼	$0·82¼
February.	0·50	0·45	0·45	0·80	0·75	0·75	1·24⅛	1·19⅛	1·19⅛	0·91	0·86	0·86
March....	0·53	0·53	0·53	0·79	0·74	0·74	1·26	1·21	1·21	0·93⅛	0·88⅛	0·88⅛
April.....	0·54⅛	0·49⅛	0·49⅛	0·79	0·74	0·74	1·19	1·14	1·14	0·88¾	0·83¾	0·83¾
May.....	0·59	0·54	0·54	0·81⅜	0·76⅜	0·76⅜	1·08	1·03	1·03	0·80⅜	0·75⅜	0·75⅜
June.....	0·64⅛	0·59⅛	0·59⅛	0·85⅛	0·80⅛	0·80⅛	0·95⅛	0·90⅛	0·90⅛	0·79	0·74	0·74
July,.....	0·67½	0·62½	0·62½	0·90⅛	0·85⅛	0·85⅛	0·95	0·90	0·90	0·84	0·79	0·79
August....	0·71⅜	0·66⅜	0·66⅜	0·93⅛	0·88⅛	0·88⅛	0·93⅛	0·88⅛	0·88⅛	0·91	0·86	0·86
September	.....	.....	.....	1·03¾	0·98¾	0·98¾	0·91⅛	0·86⅛	0·86⅛	0·91¼	0·86¼	0·86¼
October...	0·76	0·71	0·71	1·07⅜	1·02⅜	1·02⅜	0·82⅛	0·77⅛	0·77⅛	0·94	0·89	0·89
November	0·77	0·73	0·73	1·11¾	1·06¾	1·06¾	0·80	0·75	0·75	0·94	0·89	0·89
December.	0·79	0·74	0·74	1·16⅛	1·11⅛	1·11⅛	0·87	0·82	0·82	0·89⅝	0·83⅝	0·83⅝
Average...	$0·63⅞	$0·58⅞	$0·58⅞	$0·92⅛	$0·87⅛	$0·67⅛	$1·01¼	$0·96¼	$0·96¼	$0·88⅛	$0.83⅛	$0·83⅛

The exports of mineral oils from the United States during 1901 were far in excess of the previous year. The figures for the last five years are as follows:—

EXPORTS OF MINERAL OILS FROM THE UNITED STATES. (IN GALLONS.)

(1 = 1,000 in quantities and values.) (a)

Year.	Crude Petroleum.		Naphthas.		Illuminating.		Lubricating and Paraffine.		Residuum.		Totals.	
1897.....	121,864	$5,044	13,704	$1,020	804,446	$46,876	52,659	$6,732	12,247	$335	1,004,920	$60,007
1898.....	120,486	5,016	17,257	1,071	764,823	38,895	65,526	7,626	30,436	815	998,478	53,423
1899.....	118,690	5,958	18,210	1,597	783,393	49,173	71,105	8,656	21,609	658	992,007	66,042
1900.....	133,161	7,341	18,570	1,681	739,136	54,693	71,211	9,933	19,750	845	986,855	74,493
1901.....	127,008	6,098	21,685	1,743	827,222	53,491	75,291	10,260	27,596	1,255	1,078,802	72,786

(a) In addition to the above, the following quantities of paraffine and paraffine wax were exported: 1897 136,069 lb. ($5,284); 1898, 166,317 lb. ($6,363); 1899, 181,861 lb. ($7,650); 1900, 157,108 lb. ($8,186); 1901, 151,695 lb. ($7,960).

The average price of refined petroleum at New York in 1901 was 6·2c. per gal., as compared with 2·04c. per gal. at Batum and Novorissisk, on the Black Sea, which is a very wide difference in value between the two articles. Were it not for the superior quality of the United States product, as well as the superior methods of delivering the manufactured products, it would be impossible to market the quantity that is now disposed of. It must be remembered that a large percentage of the Russian refined petroleum is a by-product. Owing to the great demand for fuel petroleum, and as the crude cannot be marketed as such until the more volatile products are removed and the fire test is sufficiently raised to conform to the Government standard, it is necessary to pass it through the process of distillation, by which the smallest possible quantity is converted into naphtha and illuminating product. The much larger proportion is marketed for fuel under the name of "residuum" or "astatki."

The quantities of naphtha, illuminating, lubricating and paraffine oils exported from the United States and Russia in 1901, in gallons, were as follows:—

Country.	Naphtha.	Illuminating.	Lubricating and Paraffine.	Total.
United States.....	21,685,000	827,222,000	75,291,000	924,198,000
Russia	.....	328,732,460	38,459,820	367,192,280
Totals.....	21,685,000	1,155,954,460	113,750,820	1,301,390,280

The quantity of crude, residuum and distillate is omitted from both countries. Of the products named in the above table the United States exported 71% and Russia 29%.

The chief markets of the manufactured products exported from the United States, Russia and other countries are the United Kingdom and Germany.

The following is an official statement of the importation of petroleum and its products—illuminating and lubricating oils—into Great Britain for 1899, 1900 and 1901, in Imperial gallons, which are one-sixth greater than the United States gallon:—

IMPORTS OF PETROLEUM INTO GREAT BRITAIN. (IN ENGLISH GALLONS.)

Countries.	1899.	1900.	1901.
United States.....	166,192,455	153,776,766	162,791,209
Russia.....	69,816,972	87,765,897	78,207,684
All other countries.....	4,137,940	13,435,380	13,517,065
Total	240,147,367	254,978,043	254,516,098

The total exportation for the past two years has been nearly the same in quantity, although it will be seen that the amount imported from the United States has decreased from 69% of the total importations in 1899, to 60% in 1900, and increased to 64% in 1901, as compared with 29% imported from Russia in 1899, 34% in 1900, and 31% in 1901. A comparison of the two last years shows that the United States is increasing the sale of petroleum products at the rate of 6% yearly, while that of Russia is declining at the rate of 11%.

The average price for the United States refined petroleum at Liverpool during 1901 was 7d., or 14c. per Imperial gallon—which is one-sixth larger than the United States gallon—as compared with 6·25d., or 12·5c. per gal. for the Russian refined.

The increase in quantity has been sold at higher prices for the American products, in the face of the fact that there is a very large amount of English capital invested in the Russian petroleum fields at Baku, which would naturally be interested in the sale of the Russian product within its own limits as against the interest of the other countries. The increase in the sales of the United States product must therefore be due entirely to the superior quality of the article which is sold on its merits alone.

The exports to Germany for the years 1899, 1900, and 1901, have been made up from the countries exporting the manufactured petroleum, and embrace the naphtha, illuminating and lubricating products in gallons exported from the United States and Russna.

REFINED PETROLEUM EXPORTED TO GERMANY BY THE UNITED STATES AND RUSSIA.
(UNITED STATES GALLONS.)

Countries.	1899.	1900.	1901.
United States	128,074,786	141,626,015	150,261,515
Russia	26,310,340	29,994,478	21,914,240
Total	154,385,126	171,620,493	172,175,755

These figures also indicate the increasing consumption of the United States product. Of the total of these two countries, the United States furnished 83% and Russia 17% in 1899, as compared with 83 and 17% in 1900, and 87 and 13% in 1901. The price per United States gallon at Bremen averaged close to 9·5c. per gal. in 1901 for United States illuminating petroleum, and about 8·75c. for the Russian product.

In 1901 the United Kingdom and Germany together consumed 34% of the total exportation of the United States, as compared with 37% of the total Russian exportation. The combined exportation of these countries amounted to 313,053,412 gal. from the United States, and 100,122,124 gal. from Russia, making a total of 413,175,536 gal., amounting to 32% of the total exportation from the United States and Russia. The remainder found a market in other parts of the world.

The increase in the total production of petroleum in the world during 1901 over that of 1900 was 7,541,335 bbl., or 12%. Russia produced 51·4% and the United States 41·9% of the total output, leaving but 6·7% to be produced by all other countries. While this proportion holds true so far as the gross produc-

tion is concerned, it is not, however, a true comparison when the quantity and quality of the higher grades of illuminating, lubricating, paraffine products and other derivatives are considered. The amount of naphtha, illuminating, lubricating and paraffine products secured from the production of 69,389,-195 bbl. of crude oil in the United States is estimated to be not less than 47,560,195 bbl., amounting to 1,997,520,000 gal. Of this amount 911,120,-944 gal. were exported after deducting 151,629,462 gal. of crude, also exported. This represents 55% consumed at home, and 45% exported, while the average yield of manufactured products upon all the petroleum produced in the United States is 68·5%.

From the Russian field there were exported to other countries during 1901, 428,657,210 gal.; of this amount 14,534,990 gal. were crude and residuum, leaving 414,122,990 gal. of illuminating, lubricating, distillate and solar petroleum, as compared with 911,120,944 gal. of manufactured products exported from the United States. Therefore, for every gallon exported by Russia, the United States exported 2·2 gal., or 69% of the total manufactured products from petroleum are shipped abroad from the United States, as compared with 31% from Russia. Of the 85,168,555 bbl. produced in Russia, only 11,805,551 bbl., or 495,833,154 gal., were converted into manufactured products. This amount represents but 13·8% of the total production of crude in Russia, as compared with 68·5% of manufactured products obtained from the crude produced in the United States. In Russia 86·2% is consumed as fuel, while only 31·5% of the total production is consumed in the crude state in the United States.

Of the total manufactured products amounting to 13·8% in Russia only 15% of this amount was consumed at home, leaving 85% to be exported abroad, as compared with 55% consumed at home in the United States and 45% exported.

Russia and the United States produced 93·3% of the known output of petroleum in the world during 1901. The indications are now that Texas will redeem in a few years the place at the head of the list once held by the United States as the country producing the largest quantity of crude petroleum in the world.

The average price of the crude petroleum produced in the United States during 1901 was 95·1c. per bbl., and the total valuation was $66,417,335. The average price paid for the Russian crude petroleum during 1901 was 32·67c. per bbl., the total value being $27,824,567, which is only about 40% of the amount received from the crude petroleum produced in the United States for the same time.

These amounts added together give $94,241,902 as the price of 154,557,750 bbl. of crude petroleum produced by these countries, which is an average value of 61c. per bbl. In all the other countries producing petroleum, viz.: Canada, Peru, Galicia, Roumania, Sumatra, Java, Borneo, Japan, India, Germany and Italy, only 11,160,770 bbl. were produced, amounting, as before stated, to 7·6% of the entire known production of the world. The estimated value of this quantity of petroleum at 70c. per bbl. is $7,812,539. If this is added to the value of that produced in the United States and Russia, the total amounts to $102,054,441 for the known production of the world in 1901, and if this be

divided by 165,718,520, the total production, the average price per bbl. of the world's crude petroleum output is 61·5c.

Present Condition and Future Possibilities.—The wide range in the producing area of petroleum in the United States, and the different conditions under which it is stored, indicate an increased production in the future. Slowly but surely the conditions under which it is concentrated are being more carefully studied, and the mechanical appliances for drilling, pumping and transporting improved. In no other country has the transportation of both crude and refined petroleum in trunk lines reached the perfection that has been attained in the United States. Triple expansion pumping engines have enabled the pumps to work up to a pressure of from 600 to 1,000 lb. to the sq. in., at a minimum cost of fuel. These trunk lines and their feeders extend over hundreds of miles and connect distant fields with the refineries and the large markets of the seaboard and inland cities. The future will, without doubt, produce methods of deep and rapid drilling at moderate cost, which will reach the deeply buried petroleum producing strata when the upper strata has been exhausted. In portions of the Appalachian region it will require 6,000 ft. to reach the lowest stratum that elsewhere is known to contain petroleum. The important work of the chemist in separating noxious vapors and deleterious combinations from the lighter products of the lower grades of petroleum, producing from them superior lubricating oils, must also be a work for the future.

Geology.—The geological equivalents of the systems or ages holding petroleum in the United States, begin with the Pliocene or newest stratified rocks that are capped by the alluvium, followed by the Tertiary, Cretaceous, Jurassic, Triassic, Permian, the upper, middle and lower Carboniferous, Devonian and upper and lower Silurian. That portion lying east of the Mississippi river, and to the northwest of the main uplift of the Appalachian chain of mountains contains the known profitable petroleum fields, which are designated as the Appalachian, and the Lima-Indiana field. The strata containing the petroleum and natural gas in the Appalachian division begin with the upper Carboniferous, and extend downward to the middle Devonian. The probable area of these formations is about 55,000 square miles, extending along a northeast and southwest axis about 700 miles long and 80 miles wide. From this area is obtained the greatest supply of high-grade petroleum. In the States of Kentucky and Tennessee, however, a limited amount is produced from strata much lower in the scale. The central point of this possible productive area is not far from the southwest corner of the State of Pennsylvania, and is distant from New York, by way of the pipe-line route, 520 miles, and from Philadelphia and Baltimore, 380 miles. Near these cities the greater refineries are located, which convert the crude product into illuminating oil and other manufactured products. Two-fifths of the northern portion of this great petroleum area contain the prolific pools of Pennsylvania, New York, West Virginia and southeastern Ohio. The whole of the productive area is covered by a labyrinth of smaller pipe lines connecting over 90,000 wells, which feed the main lines that supply the inland and seaboard refineries. The Appalachian division produces over 60% of the entire output of crude petroleum east of the Mississippi river. The other division of the

productive area east of the Mississippi river, known as the Lima-Indiana field, is on the line of a much more ancient uplift (the Cincinnati arch) than that of the Appalachan field. It starts in Alabama, where the Appalachian uplift and the Cincinnati arch coalesce, as it were. The latter then takes a course a little east of north, passes through Tennessee, Kentucky and northwestern Ohio, crosses over into Ontario, Canada, and curving to the eastward finally terminates in a series of extinct volcanic islands on the east of Hudson Bay. In its southern portions it is a gentle swell without faulting to any great extent, with gentle slopes and undulations along its crest line. North of the Ohio river a branch line of uplift crosses into central Indiana in a general northwestern course. On the crest of the main line of elevation and its branches in Ohio and Indiana the greater supply of gas and petroleum is found, although there are many localities south of the Ohio river which have produced considerable petroleum from the same general topographical and geological conditions. In this last named region the conditions are lacking for the proper accumulation of the liquid and gaseous hydrocarbons.

The production in this area is secured in the Trenton limestone of the lower Silurian or Cambrian division, which is usually several thousand feet below the productive areas of the middle Devonian in the upper Appalachian field. In quality the petroleum produced is inferior to that of the Appalachian field. The yield of the more valuable and volatile products is less, and it contains 0·6% S as hydrogen sulphide, which is difficult to remove in the process of refining. This field produced 21,933,380 bbl. in 1901, which was 40% of the output of the combined Appalachian and the Lima-Indiana fields. This field also is covered by a network of smaller pipe lines connecting many thousand wells with the receiving tanks. A system of trunk lines extends as far as Chicago on the west, while to the east it connects with the other main lines reaching the Atlantic seaboard cities. There must be at least 10,000 miles of trunk line pipe from 4 in. to 8 in. in diameter that convey the crude oil from the various fields to the points of manufacture. These lines are buried from 2 ft. to 3 ft. deep in order to reduce the amount of expansion and contraction. They are constructed of wrought iron and steel lap-welded pipe in lengths of from 18 to 22 ft. On each end sharp threads are cut with a taper from 9 to 10 in., which are screwed into couplings also tapered, to make a complete fit. A large force of men are usually required to "set up" the joints to the proper tension. The trunk line pipe is tested to a pressure of from 1,500 to 2,000 lb. to the square inch.

The distance between pumping stations on the main trunk lines is usually from 28 to 50 miles. These distances can be varied more or less owing to the elevations to be overcome, by the addition of an extra line or a loop from the point of discharge, to such points as are convenient for fuel or water. The pumps employed in the service are of the highest mechanical excellence. They are flywheel-connected, triple-expansion, and built by the National Transit Co., at Oil City, Pa. The pipe line may be compared to the steel rail, and the pump to the locomotive in this method of transportation.

Performance of Pumping Engines.—A test was made of one of these pump-

ing engines in 1892 by Prof. J. E. Denton, of Stevens Institute, Hoboken, N. J., at Laketon, Ind., in which Indiana petroleum was used for fuel. The test was made while the engine was performing its regular duty of forcing 30,000 bbl. of petroleum per day through 54 miles of pipe under a pressure of 600 lb. to the sq. in., at 28 revolutions per minute. The efficiency of the mechanism was found to be 94·5%; the diameter of high pressure cylinder was 24·12 in., intermediate 38 in., low cylinder 54·0 in., with Corliss valves and adjustable cut-offs, length of stroke 36 in., with two single acting air-pumps, condensers, etc. These operated six plungers, 8 in. in diameter, set beyond the main shaft in line with the cylinders. The average horse power exerted on the pump pistons amounted to 300 H.P., with 328 H.P. developed by the steam cylinders, and average boiler pressure 150 lb. The general conclusions arrived at as the result of numerous tests carefully made showed a water consumption of but 13·50 lb. per hour per horse power at 20 expansions, which is very close to the best results of the most improved ocean liners.

Performance of Boilers.—The following is the result of the experiments with two boilers at Laketon, Ind., which supplied the steam to the triple expansion engines previously described, the fuel being crude Indiana petroleum, burned with a Cobb & Towl compressed air burner. The boilers were of the horizontal tubular type, 5 ft. in diameter, 14 ft. long, and contained 182 two-inch tubes, with a water heating surface of 1,180 sq. ft. The average evaporation, at 212°F. for 7 tests, was 16·10 lb. of water per lb. of petroleum, corresponding to 15,553 B.T.U. that were effective. The steam was perfectly dry. The average evaporation per hour per sq. ft. of heating surface was 1·9 lb. at 150 lb. gauge pressure, and 60° temperature of feed water. The air was supplied by a Root Blower at the rate of 240 cu. ft. per minute, and at about 0·5 lb. pressure per sq. in. The blower was driven by a small steam engine whose consumption of steam amounted to 1·5% of the steam evaporated by the boiler.

Quite recently Prof. J. E. Denton made a very exhaustive test of the evaporative power of the Beaumont petroleum for the Export Oil & Pipe Line Co., of Beaumont, Texas. One pound of Beaumont oil evaporated 15·1 lb. of water at 212°F., representing 14,587 B.T.U., which demonstrated that the Beaumont petroleum, for fuel purposes, is the equivalent of about 95% of the value of the Indiana crude petroleum. Numerous tests have proven that when the liquid hydrocarbons are sold by the gallon or barrel and not by weight, the calorific value is remarkably close, whether it be residuum of various grades or crude petroleum from California, Texas, Indiana or Pennsylvania.

Comparative Cost of Coal and Petroleum.—The equivalents given in the table on the following page are considered to be secured in ordinary practice. Western coal will evaporate 6·5 lb. of water from and at 212°F.; Pittsburg coal, 8·7 lb., and Beaumont petroleum, 13·5 lb., the proportion remaining the same for better or poorer results under boilers.

Alaska.—In Alaska there are remarkable surface springs of petroleum, but the climate and physical conditions of the region have for several years baffled the skill of the promoters to test them successfully.

California.—Southern California is the present great producing region of

COMPARATIVE COST OF COAL AND PETROLEUM.

Price of Southwestern Coal per Ton of 2,000 Lb.	Number of Barrels of Beaumont Petroleum to Equal One Ton of Coal.	Price of Beaumont Petroleum per Barrel to Equal Cost of One Ton of Southwestern Coal.	Price of Ordinary Pittsburg Coal per Ton of 2,000 Lb.	Number of Barrels of Beaumont Petroleum to equal One Ton of Pittsburg Coal.	Price of Beaumont Petroleum per Barrel to Equal Cost of One Ton of Pittsburg Coal.
$1·00	3·0	$0·33	$1·00	4·0	$0·25
1·25	3·0	0·42	1·25	4·0	0·31
1·50	3·0	0·50	1·50	4·0	0·37
1·75	3·0	0·58	1·75	4·0	0·44
2·00	3·0	0·67	2·00	4·0	0·50
2·50	3·0	0·83	2·50	4·0	0·62
3·00	3·0	1·00	3·00	4·0	0·75
3·50	3·0	1·17	3·50	4·0	0·88
4·00	3·0	1·33	4·00	4·0	1·00
4·50	3·0	1·50	4·50	4·0	1·13
5·00	3·0	1·67	5·00	4·0	1·25
6·00	3·0	2·00	6·00	4·0	1·50

the Pacific coast, with its most remarkable recent developments of a greatly increased amount of fuel petroleum in a region that is destitute of valuable coal deposits. While nearly all of the fields increased their production during the year 1901, the great increase came from the comparatively recent pools about Bakersfield in Kern County, which are known as Kern, McKittrick, Sunset and Midway pools. A very remarkable increase in production is recorded for these four pools. The production of the group for 1900 was less than 900,000 bbl.; for 1899 it was 15,000, and for 1898 it was 10,000; nothing being recorded for 1897 from this county. The production for 1901 from 447 wells—which was sold at an average of 40c. per bbl.—suddenly increased to 4,500,000 bbl. under adverse conditions of congested railroad transportation and overflowing tanks. Had these been ample the production would have been considerably increased.

The production of the counties of the State for 1900 and 1901 is as follows:—

County.	1900.	1901.
Kern	899,500	4,493,455
Los Angeles	1,370,263	2,188,633
Fresno	533,000	780,650
Ventura	418,000	463,127
Orange	872,200	794,565
Santa Barbara	153,750	135,900
Santa Clara	771	.....
Unapportioned	295,000	.....
Total	4,294,484	8,786,330

The value of the production for 1900 amounted to $4,078,975, an average of about 94c. per bbl.; that for 1901 amounted to $4,974,540, or 57c. per bbl. There were a large number of tanks constructed in the Kern river valley to furnish storage for this petroleum by the Pacific Coast Oil Co. Between 30 and 35 of these large tanks were completed during the year 1901, and the number has been considerably increased at this writing. The most important undertaking was the construction of a large refinery at Port Richmond, on the waters of San Pablo Bay, near San Francisco, and its connection with the Bakersfield district in Kern County, 270 miles distant, which will insure an outlet for the petroleum that this field is capable of producing, as well as supplying the section near San Francisco with an abundance of cheap liquid fuel that has already greatly contributed to the prosperity of that city and the surrounding section.

The problem of conveying the heavy petroleum, ranging from 14 to 16°, produced in the Kern river pools—which corresponds to 0·972 and 0·945 sp. gr., weighing on an average of 8 lb. to the gal. when the weight of water is 8·331 lb. to the gal., in an 8-in. line for any distance—is one that has been heretofore unsolved by any pipe transportation company in the United States or elsewhere.

Wells are now being drilled with fair indications in Humboldt County, in the northern portion of California.

Colorado.—Colorado has been an important producer of petroleum in what is known as the Florence field since 1887, and has produced a very considerable quantity of petroleum of a very fair quality, which in 1901 amounted to over 460,000 bbl. At Boulder, toward the close of the year, a well on the McKenzie farm, after passing through a number of pay streaks at 900, 1,200, and 1,540 ft., at about 2,720 ft. found a pay streak containing a considerable amount of excellent petroleum of a gravity of 42°B. This was followed by numerous other wells, nearly all of which have found more or less petroleum; however the deep wells thus far have found only moderate quantities of this superior petroleum, which has had a rather discouraging effect on the development. A great number of stock companies were formed, and an immense amount of capital invested. Companies commenced to drill along the foot hills of the eastern slope of the Rocky Mountains at Colorado Springs, Golden, Boulder, Fort Collins, and extending to the Wyoming State line. By the latter part of February, 1902, there were 48 wells drilling in the State and 100 rigs built. The greater part was in the region northwest of Denver. The production thus far has been secured from the sandy beds of the upper Cretaceous formation.

Kansas.—During 1901 the petroleum field in southeastern Kansas produced 179,150 bbl. of oil, valued at $154,373, which was an average of 86·2c. per bbl. The production for 1900 was 74,714 bbl., thus showing a gain the past year of 139·78%. The value of the natural gas produced in 1900 was $356,900, while the total value of all the natural gas in the region west of the Mississippi river amounted to only $449,847. The value for 1901 will show a material gain over that of 1900. The advantages of natural gas as a source of heat, light and power, fully described elsewhere in this volume, apply with equal force to the gas developed in Kansas, Indian Territory and Oklahoma.

Texas.—The great event in this region the past year was the unexpected flow of a solid stream of petroleum 160 ft. in height from a well drilled by Capt. A. F. Lucas and his associates, Mr. J. M. Guffey and Mr. John Galey, 4·5 miles south of Beaumont, in Jefferson County, and only 20 miles from the deep water harbor on the Gulf of Mexico. This wonderful discovery marked the beginning of a new era in the history of our petroleum development and startled the operators in all the important productive areas in the United States and the Old World. It was not until the quality of the petroleum thus developed was proven to be inferior for illuminating and lubricating purposes that their fears commenced to subside. The immediate rush to secure territory in this neighborhood was unprecedented. Many practical operators from other petroleum regions became interested and, after looking over the field and finding it impossible to secure any territory upon terms that were considered favorable, withdrew. Then

followed a swarm of promoters, who promised the land owner almost anything he asked, or took options on the land at high prices. In the meantime a vast number of stock companies were formed, many of them controlling but a few acres. The promoters had no trouble to convince other parties with money that the whole plain surrounding the mound known as Spindle Top was saturated with petroleum,—that the available territory reached far back into the interior, and that the wells flowed by hydrostatic pressure. These promotors, assisted by irresponsible newspaper adventurers, disposed of vast quantities of stock which had little or nothing to represent it. If there had been such a quantity of petroleum so easily secured, it would have had little value. Thus far it has been possible to sell only a portion of the petroleum that has been produced, and the portion unsold is now tanked at Spindle Top. A few months of reckless drilling sufficed to make it evident that the production was confined to an elliptical area 3,500 ft. by about 2,000 ft. in dimensions, embracing about 170 acres of land on the elevation known locally as Spindle Top, because of its peculiar shape. By the close of 1901 there were 138 producing wells drilled upon this elevation, 55 of which ranged from 75,000 bbl. to 1,000 bbl. per day, and which belonged to companies that could market their oil. The remaining 77 were not producers to any extent owing to the fact that no market could be found for their petroleum, although some were practically dry or very small wells. In addition to these 138 wells there were 28 others that had been drilled, and were known to contain no oil. The production to the close of 1901 will approximate closely as follows:—

PRODUCTION AT SPINDLE TOP, TEXAS, DURING 1901.

	Barrels.
Produced and sold	3,593,113
Stock on hand	1,592,770
Estimated loss by conflagration and waste	775,000
Total production	5,960,883

The petroleum sold and tanked therefore amounts to 5,185,883 bbl., which, at 18c. per bbl., amounts to $933,459. The outlay in the field, not including the amounts paid for real estate, from January 10, 1901, to the close of the year, has been carefully estimated by Mr. L. C. Sands, of the Oil Well Supply Co., as follows:—

138 producing wells at $7,429 each complete	$1,025,202
46 drilling wells at $4,000 each	184,000
28 abandoned wells at $15,611 each	437,108
2,895,900 barrels iron tanks at 25c. per barrel	706,450
33,150 wooden tanks at 37½c. per barrel	12,425
904,500 barrels iron tanks building at 12½c	112,000
190,000 barrels earthen reservoirs at 7·2c. per barrel	13,750
10 pump stations, average $7,770 each	77,700
125 miles of pipe, from 10-in. to 4-in., and laying same	550,200
16½ loading racks for 161 cars at $822·30 each	13,250
325 tank cars purchased by oil companies at $80 each	260,000
3 refineries, in process of erection at Port Arthur	265,000
84 rotary drilling outfits at $3,500 each	294,000
Total amount invested to January 1, 1902	$3,951,085

From the above figures it appears that the capital expended in this field has been $4·23 for every barrel of oil produced in 1901. The above figures do not include the immense prices paid for lands upon which these wells are located.

In many instances small parcels were disposed of at the rate of $120,000 an acre. It is also impossible to estimate the amount paid by the small investors for stock in worthless oil companies. The depth of the wells are less toward the center of the mound, where some found the pay streak at about 900 ft. Those along the edges of the productive area are usually deeper, one finding the pay streak as low as 1,190 ft. Away from this mound wells have been drilled from 2,200 ft. to 2,600 ft. in depth that have not encountered the limestone with more or less free sulphur that is saturated with petroleum and natural gas inside the magic circle. The formation seems to vary as the drillers report it from 25 to 85 ft., or even more, in thickness.

The following analysis of this rock, taken from the Texas Geological Survey, was made by Mr. S. H. Worrell, of the University of Texas: CaO, 54·89%; CO_2, 42·45%; S (free and in organic combustion), 1·58%; S (as H_2SO_4 in combustion), 0·21%; Fe_2O_3 and Al_2O_3, 0·50%; MgO, trace.

Some samples carry a much larger proportion of free sulphur than is shown in the above analysis. The sand immediately above the cap rock contains pure sulphur crystals as large as hazel nuts. Above the cap rock are a series of loose and compact sands, with considerable iron pyrites in small crystals. There are also irregular beds of clay with an occasional bed of coarse gravel followed by an irregular sandstone which in some instances has contained considerable reservoirs of natural gas. There are other elevations in this portion of Texas from 10 to 60 miles southwest of the one at Spindle Top that have indications of petroleum accompanied in some instances with big flows of natural gas. The condition of the mass of cap rock holding the petroleum in this field is a special one, and is limited to the are as now defined. The floor of the new strata has been disturbed by the intrusion of the older ones in a number of localities in Texas and Louisiana, accompanied by thermal springs, which have carried in solution large deposits of salt, lime, and magnesia. In some instances these mounds have approached the condition of incipient volcanoes from which sublimed sulphur has found its way to the surface, sometimes pure, in other instances as iron pyrites. The temperature of the petroleum at Beaumont is between 80 and 83°F.

Two hundred miles northwest of Beaumont the Corsicana field is located, which for several years has produced a very remarkable petroleum. In 1901 it amounted to about 800,000 bbl. of a remarkably high-grade petroleum, very similar to the better grades found in Roumania and Galicia in Europe. A modern refinery here transforms this product into the higher grades of illuminating and lubricating products.

At Sour Lake, 20 miles northwest of Beaumont, at about 900 ft. depth, salt and sulphur water was encountered which made temporary flows in considerable volume at a temperature of over 100°F. At Sour Lake and at Jennings several wells have encountered large deposits of petroleum in loose sand. At the former locality this deposit was encountered at 680 ft., and in the latter at over 1,800 ft. The loose sand bridges over and retards the flow until it is removed by the drill when the well is usually ready to spout again. These difficulties will gradually be overcome by experience and wells of larger diameter, as similar difficulties have been overcome in Russia and Roumania. In the former country great

quantities of loose sand are vomited out with the petroleum in the flowing wells, or if bailed too deep the loose sand fills up the well and must be patiently removed before it will produce again. About 12 miles northwest of Sour Lake, at Saratoga, two wells have lately produced considerable petroleum of heavy gravity.

There are a great many localities in this State where surface indications of petroleum, natural gas and bitumen have been reported, and probably many more exist that have never been reported. The following is a list of the counties in southeast Texas in which indications of petroleum are said to exist, either as oil or gas flows or solid bitumen: Martin, Washington, Harrison, Trinity, Smith, Anderson, Houston, Nacogdoches, Shelby, San Augustine, Tyler, Jasper, Hardin, Jefferson, Chambers, Brazos, Harris, Grimes, Limestone, Bastrop, Colorado, Caldwell, Atascosa, Duval, Uvalde, Webb, Starr, and Hidalgo; also Pecos, Reeves, and El Paso, in the extreme western portion of the State. Over the great area of this State the future will determine many profitable pools.

Wyoming.—There are many pools in this State which are known to contain petroleum in quantity in a range of strata that begins with the Carboniferous and extends up to the Laramine. Numerous wells scattered over a large portion of the State have proven the existence of the article in quantity, but their isolated locations have prevented the marketing of their products. But one pool is operated in Wyoming, that is known as the Salt Creek Pool, 50 miles north of Casper, which produces a remarkably pure lubricating petroleum—the production being about 5,000 bbl. annually, valued at from $6 to $7 per bbl.

Washington and Oregon.—Wells are now being drilled in these States, with fair indications.

Western Oil and Gas Production.

A remarkable increase in the production of petroleum has been recorded during the past five years in the vast region west of the Mississippi river. Oil has been discovered in several of the Rocky Mountain States, and there is every indication that a considerable portion of the world's future supply of petroleum will be derived from these sources. In 1896 only 2·85% of the total production of the United States was found west of the Mississippi. In 1897 the proportion increased to 4%; in 1898 to 6%; in 1899 to 6·5%; in 1900 to 8·5%, and in 1901 to 20%. And there is every indication that 1902 will witness a gain of 33% over 1901. The quantity produced in this section in 1901 was 13,847,792 bbl., while the estimated production for 1902 is placed at 25,000,000 bbl. These figures indicate with what strides the production of the West is overtaking that of the East.

The petroleum produced in southeastern Kansas is from strata that represent the equivalent of the lower Coal Measures of the Appalachian region immediately above the Sub-carboniferous limestone, which would bring it to correspond with the salt sand and "Big Injun" production in West Virginia. This same formation continues on a southwest course through western Indian Territory into the northeastern portion of Texas with increasing thickness of the measures in this direction. The production from this section comes from the oldest strata so far developed in the region west of the Mississippi river; all the other measures so far producing petroleum in this region are of a later formation.

PRODUCTION FOR 1901 BY STATES EAST AND WEST OF THE MISSISSIPPI RIVER.
(IN BARRELS.)

East of the Mississippi River.		West of the Mississippi River.	
Ohio	21,648,000	California	8,786,330
Pennsylvania	12,625,400	Texas	4,398,660
West Virginia	14,177,100	Colorado	460,520
Indiana	5,757,080	Kansas	179,150
New York	1,266,600	Wyoming	5,400
Kentucky and Tennessee	137,300	Indian Territory and Missouri	9,330
Illinois and Michigan	3,100		
Total	55,554,780	Total	13,834,390
Valued at	$59,534,735	Valued at	$6,882,600

From the figures in the above table it will be seen that 20% of the total production of the United States came from west of the Mississippi river in 1901, the value of which was not quite 10%, as compared with 80% in quantity and about 90% in value produced east of that river.

The great inland section of northwestern Texas and New Mexico, reaching up to the Canadian border and beyond into the great valley of the Athabasca and Mackenzie rivers, affords great diversity of conditions of geological and structural possibilities that have not as yet been sufficiently examined. The great mountainous region in Colorado, Utah, Wyoming, and Montana, with cross ranges, bringing up the older igneous rocks on whose flanks repose the more recent measures,—which in many instances have indications of petroleum,—have only in a few instances been tested.

THE PRODUCTION OF PETROLEUM IN FOREIGN COUNTRIES DURING 1901.

BY PAUL DVORKOVITZ.

INTRODUCTORY.

AMONG foreign countries exploiting petroleum Russia, of course, stands foremost, and in regard to the development of the Russian fields there is not much to be said. The area has been somewhat extended, and the various outlying districts have been exploited with no specially remarkable results. The gradual change which has been coming over the Russian industry still continues and spouters are becoming a greater rarity, while the pumping wells are supplying a larger proportion of the output from approximately the same average depths as in the year 1900. During 1901 the crisis which had occurred in the previous year was gradually being overcome and although prices have not yet reached the high figure which prevailed two or three years ago the condition of the industry has become much firmer and trading conditions for the next year will, no doubt, prove more profitable to the operators.

One of the chief features in connection with the English companies working land in Russia has been the endeavor on the part of the Russian Petroleum & Liquid Fuel Co., which up to the present time has been the most prosperous, to bring about an amalgamation with the Baku Petroleum Co. The storm which these proposals raised among the shareholders of the former company will be

well remembered. So controversial was the character of the meeting at which these proposals were presented that the matter was altogether dropped. It may be as well to state that the chief object of the Russian Fuel Co. was to obtain a larger area of petroleum land to supplement their own small, but at present very prolific, property.

As far as the trade in other and more distant countries is concerned there is little to chronicle—no great development has occurred, but the industry as a whole in the Far East has made moderate progress. If there has been any special expansion at all it must be looked for in the direction of the use of liquid fuel and in handling and transporting the oil. Chief among the advances which have been made in the use of liquid fuel, stands the voyage of the Shell tank steamer "Clam." This vessel had been run for two years on petroleum, during which time it traversed 85,000 miles and the experience gained on this ship confirmed the previous claims which had been made for the use of the liquid form of fuel. In the early days of the carrying of oil in bulk, it was thought that so large a quantity as 4,500 tons of oil could not be carried in this manner, an idea which has since been successfully confuted by Sir Marcus Samuel and now, there are tank steamers belonging to the Shell Transport & Trading Co. capable of conveying 9,000 tons while four additional steamers are to be added to this fleet, having a carrying capacity of 11,000 tons each.

Other steamship companies have followed in the steps of the pioneer company and now the North German-Lloyd, the Hamburg-American, the East Asiatic and the China Mutual companies are numbered among the users of this fuel. The Shell Transport & Trading Co. has launched several new large tank steamers which have been used for the extension of the company's trade with Australia, where it has erected considerable storage accommodation. In this connection it may also be mentioned that the company has also entered into a contract with the Guffey Petroleum Co. of Texas to ship its oil to European markets, and the Borneo fields belonging to the same company have also shown considerable progress during the past year.

A special impetus was given to the scientific study of petroleum at the Petroleum Congress in August, 1900, and since that time various schemes have been formulated, and one at least has been put into practice, while there are also endeavors being made in various countries to provide some means whereby specially trained men can be supplied to the oil fields and refineries. Another outcome of this Congress was the organization of a number of national committees formed for the purpose of centralizing the various developments of the industry in each country. In addition to Great Britain, France, Roumania and the United States have now specially constituted committees for this work.

SOUTH AMERICA.—*Brazil.*—The oil deposits occur chiefly in shales which were reported upon very exhaustively in THE MINERAL INDUSTRY, Vol. IX., to which there is nothing new to add.

Colombia, Venezuela, etc.—In these States are surface indications of the existence of oil deposits, but up to the present nothing has been done in the way of systematic exploitation. The native population obtain the oil in a primitive manner and use it mainly for domestic purposes. The Venezuelan oil is very

dark in color and has a sp. gr. of 0·95. Ecuador is also reported to possess a rich petroliferous region near Santa Elena, though it has not yet been exploited. The oil is very heavy having a sp. gr. varying from 0·97 to 0·985.

Peru.—The development of the petroleum industry, chiefly in the Province of Piura, has not made much headway during 1901, although work is being carried on in various districts. Geologically, the district is chiefly Tertiary and closely resembles the Californian oil belt. The Faustino Piaggio Petroleum Co. has operated a number of wells near Zorritos, two of which yielded 75,000 bbl. per annum. The oil obtained is dark brown in color, with a sp. gr. of from 0·81 to 0·84, and yielded kerosene and lubricating oils. There is also a heavier petroleum with a sp. gr. of 0·94 produced in this neighborhood in small quantities. The Pacific Petroleum Co. has a large tract of land in which about 60 wells have been sunk, yielding about 1,000 bbl. weekly. The average depth of the wells is 500 ft. and it is reported that few if any have turned out dry. The petroleum is brown in color with a sp. gr. varying from 0·834 to 0·848. It yields approximately 30% of kerosene, 10% benzine and 50% of fuel oil. In addition a French company has been working here for several years past producing about 150 bbl. a week from a dozen or so wells.

EUROPE, ASIA AND AFRICA.—*Algeria.*—Although the oil deposits of Algeria have been very extensively investigated, little practical work has been done up to the present time. One or two companies have been formed for the working of the deposits but merely preliminary steps have been taken for the sinking of wells.

Austria-Hungary.—The Galician oil industry occupies a very unsatisfactory position in the oil-producing countries of Europe. It has one of the largest oil-producing areas in the world, which will probably be largely developed in the near future. The production of oil in Russia and Roumania must necessarily hamper the development of the Galician industry and internal factors have also hindered its progress. In 1900, according to the official report of the Chamber of Trade and Commerce of Vienna, unfavorable conditions prevailed for the Austrian industry. The question of tariff and freight charges in that year were not at all favorable for the home industry and so far as the output went, the district of Schodnica, which had been regarded as the most important oil-producing field, retrograded, while the districts of Urycz and Boryslaw showed some advance. The producers of Galicia have had to realize that they were not able to supply sufficient crude oil to meet the home demands, and the consequence was that oil was obtained from Russia and Roumania. The paraffine industry, however, has shown more vitality and a greater advance, although even here the imports have been large. The kerosene industry has made but little progress, both Germany and Russia having endeavored to exclude Austrian competition by levying high duties. In addition, the German method of testing kerosene for its paraffine contents has not been favorable to the interests of Galician producers. There is however a movement in progress for connecting the Galician water-ways with the German canal system, via Oderburg, which will bring Galician exporters into touch with the East Prussian provinces of Silesia, Posen, Brandenburg and Pomerania.

One of the chief features of the year was the drilling of a spouter near Kasmachz in the Kossova district. The chief center of boring, however, has been at Boryslaw, where many wells have been sunk to the deeper horizons yielding a regular flow of from 2 to 3 tank wagons daily. One of them, drilled by the Karpathen Actiengesellschaft, produced 5 tank wagons per day.

At the present writing no figures are available to show the movement of the Galician industry in 1901, but in some directions a slight progress has been made. Statistics for the year 1900 are as follows:—

	Production.	Shipments.	Pipe Lines.		Reservoirs.		Borings and Hand-Dug Wells.			
								Borings.		
	Metric Tons.	Metric Tons.	No.	Length Km.	No.	Total Capacity. Tons.	Hand-Dug.	Drilled.	Exploited.	Total
Stanislaw District	11,244	13,230	2	17·5	199	45,000	32	20	131	151
Drohobycz	221,696	284,990	10	94	763	115,200	92	151	751	904
Jaslo	93,394	118,440	13	95	698	75,600	108	111	713	824
Krakau (Rabka)	.....	.....	.....	.....	.....	.....	1	1	.....	1
Totals	326,334	366,660	25	206·5	1,660	195,800	233	286	1,595	1,980

Production, in tons, for the last five years.

1896	339,765	1898	323,146	1900	326,344
1897	309,626	1899	321,680		

With the exception of Protok oil, all Galician crude oils contain paraffine, in amount varying from 3 to 7%. The residue left after distilling benzine and burning oil, is used for the manufacture of lubricating oil and yields paraffine. The lubricating oils contain paraffine and in addition to an inferior appearance, they apparently possess higher viscosity, which, however, does not add to the lubricating quality; as a result consumers now ask for lubricating oils free from paraffine. In the crude oil the paraffine is present in the form of proto-paraffine and ozokerite, which assumes a crystallized form only by distillation.

A modern refinery in Galicia consists of an oil reservoir, a crystallizing vessel, an ice-making machine, a filter press, an hydraulic cold press, a paraffine refining plant and a paraffine filtering plant. The oil reservoirs have a closed steam coil inside to warm the oil in order to remove the water. Should the oil contain water when admitted into the crystallization chamber ice will be formed, producing a stoppage of the filter presses, as well as a breakage of plates. An attempt was made to refine the oil before separating the paraffine, but the oils became dark in color, and required a second refining.

The crystallizing chamber consists of vessels with double linings. Three refrigerating machines are used: the ammonia machine (Linde), the sulphuric acid machine (Pictet), and the carbonic acid machine.

Dutch East Indies.—The Royal Dutch Petroleum Co. in Sumatra produced 2,350,000 cases of kerosene during the first nine months of 1901 compared with 900,000 cases during the same period of 1900, and the total production for 1901 will probably exceed 3,000,000 cases. The Moeara Enim Co. also produced a considerable excess over the previous year's output, the total amounting to approximately 2,000,000 cases. The Babat field, from which good results were expected, has proved very disappointing. The Sumatra Palembang Co., which produced 747,000 cases during 11 months of 1900, will probably equal this out-

put for 1901. Other companies are also at work on this island, chiefly the Mining & Timber Trading Co. in Lower Langkat, whose output for 1901 will, in all probability, exceed 500,000 cases. The Moesi Ilir Co. is erecting a new refinery at Palembang. This company disposes of its paraffine and liquid fuel to the Shell Transport & Trading Co. The total output of the Sumatra wells during the fiscal year 1900-1901 was 169,842,000 liters.

In regard to the working on the Borneo fields great progress has been made during the past year. The area of the property of the Shell Transport & Trading Co. here is about 500 sq. miles, the bulk of this having been ascertained as oil bearing. In 1898 the exports amounted to 6,747 tons; in 1899, 33,711 tons; in 1900, 76,051 tons, and in 1901, to more than 100,000 tons. The average production of crude oil during the first month of 1902 amounted to over 3,000 tons per week. The refinery belonging to this company when fully equipped will be able to deal with 1,000,000 tons of crude oil per year. The company owns 30 ocean-going steamers having a dead weight capacity of 120,000 tons. In addition to this for their large foreign trade it has 31 ocean depots distributed among Egypt, India, China, Japan and Australia, while 11 new installations are in progress. The storage capacity available at the present time amounts to 220,000 tons which is being supplemented by 26,000 tons. Moreover, 320 subsidiary depots are scattered throughout the Eastern Hemisphere.

In Java the Deutsch Petroleum Co. produced during 1901 an average of 140,000 cases monthly compared with 136,000 monthly in the previous year. The Java Petroleum Co. has not been so prosperous during 1901 as previously, when its output amounted to 10,000 cases of kerosene per month. The Java fields are not very attractive to capitalists as, although oil is found in many places and in various quantities, there are no very rich deposits. The figures for the production of 1900 in the different fields were as follows:—

	Cases.
Java	1,637,000
Sumatra, by the three companies	8,846,000
Borneo, about	700,000
Small refineries in Java and Sumatra, not mentioned in above, about	200,000

Egypt.—Although the work in this field is not of a very extensive character, prospecting work is still going on, and according to some reports good results are anticipated. The Oil Well Supply Co. of Pittsburg has been putting down several borings at Gebel Zeit on the Gulf of Suez on behalf of the American syndicate. The oil is struck at 2,350 ft. and is said to be of a good quality and, if all reports of the possibilities of the Egyptian petroleum industry may be relied upon, there is an excellent future ahead. In the meantime Roumanian oil is making its way among consumers and during the year 1900, 2,230 tons were discharged at Suez for domestic use.

Italy.—During the year 1900 illuminating oils were imported into Italy to the extent of 73,807 quintals. The bulk of this was American, while the proportion of Roumanian oil imported showed a decrease over the previous year. As far as production is concerned progress has been made though not of a very striking character. The places of occurrence and the quality of the oil were dealt with in THE MINERAL INDUSTRY, Vol. IX.

India.—The two chief oil-producing centers of India are Burma and Assam. The production has made great progress in recent years, especially since 1898, as shown by the following figures:—

	Gallons.	Value. Rupees.		Gallons.	Value. Rupees.
1890	4,132,000	283,173	1896	15,044,500	1,788,600
1891	6,554,500	362,790	1897	19,099,000	2,257,800
1892	8,479,900	363,600	1898	18,973,800	1,018,460
1893	10,463,900	771,100	1899	32,934,000	1,695,200
1894	11,452,600	1,126,700	1900	37,729,200	2,231,395
1895	1,300,300	1,539,100			

Japan.—The Japanese oil fields, especially that of Echigo, have made good advance during the year 1901, although the principal districts, Amase and Kamada, have shown some signs of a declining production. The Kitno district has attracted considerable attention and a good supply of oil has been obtained from the wells at the Nagaoha Industrial Co., the wells yielding about 800 gal. a day. Several other companies also have been working in this field. Altogether it is stated that about 70 concerns of an aggregate capital of 15,729,460 yen are engaged in the exploitation of petroleum lands.

From a consular report which was drawn up on the Japanese industry a number of interesting facts may be gathered. It is pointed out that the oil fields of Hokkaido are attracting a good deal of attention and that a large supply of oil is obtainable therefrom.

The crude oil output from the various Japanese fields from 1890 to 1899 was as follows:—

Year.	Output of Crude Oil.	Quantity of Kerosene Produced.	Year.	Output of Crude Oil.	Quantity of Kerosene Produced.
	Gallons.	Gallons.		Gallons.	Gallons.
1890	2,159,640	443,846	1895	5,935,080	688,040
1891	2,282,525	516,576	1896	8,273,480	666,642
1892	2,893,852	538,210	1897	9,179,434	1,044,110
1893	3,737,536	434,857	1898	11,145,457	717,101
1894	6,033,844	566,886	1899	18,853,918	1,349,126

In regard to the import trade of petroleum in Japan, the year 1900 in spite of the progress made by the Japanese fields themselves, shows a large increase over the previous year, amounting to 67,842,324 gal. compared with 52,421,837 gal. in 1899. The figures for 1900, however, fall slightly short of that for 1898 when imported kerosene amounted to close to 68,000,000 gal. One of the branches of the petroleum industry which has made great progress in Japan during the last few years is that of the importation of lubricating oils; in the year 1900 the total importation amounted to approximately 11,000,000 gal., the bulk of which was shipped from the United States.

The Japanese oil fields were described in detail in THE MINERAL INDUSTRY, Vol. IX.

Persia.—There are rumors of the formation of a Belgian company for petroleum exploitation in Persia.

The Persian petroliferous region extends along a line N.E. and S.W. from Shahku, on the Turco-Persian frontier, to the eastern side of the Persian gulf. The northern part of this basin has its center at Kasharashirin, near Shahku.

Round this village are numerous pits of a depth of about 32 ft. This deposit is situated on an Eocene axis of sand and marl, and the Kurds exploit it in a most primitive manner, contenting themselves with collecting the oil from the pits every four or five days, an average output of 10 bbl. being collected each time. The petroleum is very liquid and of a greenish color. It is refined on the spot. In the center of the Persian basin, parallel to the Bakhtiari Mountains, is the petroliferous district of Lauriston. This district also belongs to the Eocene formation and is characterized by the same blue clays which are found in Galicia. The petroleum deposits are in the neighborhood of important salt and sulphur deposits. The existence of petroleum is conspicuously shown at Chouster. The oil is of a special quality, being of a yellow color, very clear, almost transparent and of a sp. gr. of 0·773. South of this station and a few kilometers from Ram-Armuz are the natural springs of Chardin, one of which has a regular output of about 22 gal. per day. Natural petroleum springs also exist near the Persian convent of Naumzady, Haf-Cheide. These springs, which have an output of about 1 bbl. per day, produce an oil of a greenish color and of a sp. gr. of 0·927. The southern point of the Persian basin is on the shore of the Persian gulf, Dalike being its most important station. In this district, work has been seriously started, which unfortunately could not be brought to a successful finish owing to the inclemency of the weather in the summer, the bad quality of the water, which corroded the boilers, the high cost of fuel, and especially the pillaging by the neighboring tribes. The Persian Bank Mining Right Corporation, which holds the concession of this property, is under the control of Mr. Kmentt. The workmen brought from Galicia as well as those from Baku were not able to stand the climate. The Dalike petroleum is heavy and bituminous, and, according to Redwood, has a sp. gr. of 1·016. Investigations are to be made shortly near Talish, on the shores of the Caspian Sea, where abundant traces of petroleum exist. Drinkable water and cheap and abundant liquid fuel from Baku are obtainable and the natives are better policed than on the Persian gulf.

Roumania.—The petroleum industry of Roumania at the beginning of 1901 attracted a considerable amount of attention chiefly from the fact that the endeavor of the Standard Oil Co. to obtain the monopoly of the Roumanian pipe lines had only just been brought to a conclusion. Without entering into the merits or demerits of this affair, it is sufficient to say that Roumania is undoubtedly in great want of capital for the exploitation of its petroleum fields. A number of companies were formed during 1901, including the Telega Oil Co., of London, operating the Telega district; the Bustenari Poiana Oil Co., at Poiana Verbilau; the Roumanian United Petroleum Co., at Poiana, Baicoi and Provitza, and the Parsani Petroleum Mappij, of Amsterdam, at Recea, near Bustenari. In addition there were also a number of local companies.

The production during 1901 has been larger than that of the preceding year to the extent it is estimated of about 25,000 tons, a large proportion of which was provided by the Steaua Romana Co.

Russia.—The year 1901 shows a large increase in the production, as compared

with the previous year, the statistics being respectively 11,475,200 and 9,782,721 metric tons, equivalent to 80,945,247 and 72,018,743 bbl., respectively.

The output for 1901 was obtained from the various districts in the following proportions:—

Field.	Percentage of Total Production.												
	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.
Balakhany	39·5	32·0	31·3	24·4	21·9	23·4	20·4	23·4	23·8	22·4	21·8	20·6	17·8
Bebe-Aibat	8·4	7·9	8·7	11·6	14·6	11·4	12·5	18·2	14·9	19·9	15·2	18·2	19·7
Romany	.....	0·8	4·8	14·3	22·5	20·7	29·5	20·2	22·8	20·7	17·6	18·9	18·0
Saboontchi	51·1	59·3	55·2	49·7	41·0	44·5	37·6	38·2	38·5	37·0	43·8	41·4	41·9

It will be seen from this table that the largest production has again been obtained from the Balakhany-Saboontchi district, the production of which was obtained from pumping wells to the extent of approximately 6,000,000 tons and by spouters about 600,000 tons, while the Bebe-Aibat fields supplied approximately 1,500,000 tons by pumping and over 500,000 tons from spouters.

This increased supply has been obtained with but slight increase in the average depth of the wells which is evident from the following table:—

Field.	Depth of Wells.							
	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Balakhany	640	624	701	696	720	795	749	749
Bebe-Aibat	814	1,261	1,215	1,472	1,601	1,309	1,211	1,239
Romany	1,108	1,080	1,214	1,295	1,439	1,389	1,428	1,456
Saboontchi	1,020	1,080	1,080	902	966	994	847	980

During the greater part of the year the large spouter showed unmistakable signs of disappearing but toward the close there was a revival, more especially in the Bebe-Aibat district, which brought the total output from spouting wells for the month of November far ahead of any previous figure throughout the year.

The stocks of crude oil at Baku at the close of the year compared with the previous year were:—

	Jan. 1, 1901.	Jan. 1, 1902.
At the well	1,088,342 barrels.	2,058,988 barrels.
At the refineries	4,478,881 barrels.	6,850,733 barrels.

The number of wells sunk during the year amounted to 355, compared with 434 in the previous year. In regard to prices during 1901 there have been some considerable fluctuations, marked chiefly by a tendency toward decline. In January the price of kerosene in tank wagons was 20·58 kopecks and in April 8·48, and for crude oil at the wells 11·42 kopecks in January and 7·37 kopecks in April. Residuals stood at 13·58 kopecks in January and 9·93 kopecks in April. Later, however, the prices began to strengthen slightly, and reached in July 13·75 kopecks for kerosene, and 8·4 kopecks for crude. The price for residuals (not taking into account the slight temporary rise from 7·82 kopecks in September to 8·19 in October), was continually shrinking during the whole period. The year ended with prices at 7·75@8 kopecks for kerosene, 5·25@5·5 kopecks for crude, and 6·25 kopecks for residuals.

The monthly prices during 1901 are shown in the subjoined table:—

Month.	Refined.		Residuals. Kopecks per Pood.	Crude. Kopecks per Pood.
	Inland. Kopecks per Pood.	Export. Kopecks per Pood.		
January	14·34	20·00	13·09	11·56
February	12·75	19·72	13·56	11·41
March	9·87	19·00	13·12	10·12
April	8·75	12·87	12·75	9·81
May	6·70	8·25	11·70	9·50
June	7·69	9·72	9·56	8·31
July	9·30	12·60	9·67	8·95
August	8·12	11·50	7·53	7·12
September	7·19	7·85	7·69	7·00
October	8·90	10·12	10·09	7·12
November	7·87	9·25	8·12	7·28
December	7·06	8·09	6·97	6·00

NOTE.—1 kopeck equals $0·0051; 1 pood equals 36·1132 lb.

As for prices of Russian oil in foreign markets, kerosene moved from 106·6 kopecks in January, in London, to 113 in February and March, when it began to fall until it reached its lowest level, namely, 85·1 in June and July. Then followed a further uninterrupted rise and the year ended with the quotation at 111·75 kopecks per pood.

The fall in the prices of crude oil has had a particularly ruinous effect upon those who did not possess freehold plots of land, or plots leased some years ago, but who are working on the Government lands at Bebe-Aibat leased by auction at extremely high royalties, and which in some cases exceed the price of crude oil at the present time. This brought about an intention to petition the Government to replace the payment per pood by one in the form of a percentage of the production. This is an exceedingly important and complicated matter, and at the time of writing is under the consideration of the Government, the large producers having voted solidly against it, the design being supported only by small producers.

The export of Russian oil to foreign countries has made some progress during the year though the inadequate facilities for transporting the oil from the producing centers has undoubtedly hampered its further expansion and will restrict it until conditions are changed. Organization is still the one great desideratum of the Russian industry. The total exports from Russia (via Batoum and Novorosisk) for 1900 and 1901 were as follows:—

EXPORTS OF PETROLEUM FROM BATOUM. (BARRELS OF 42 GALLONS.)

	Crude and Residuum.	Lubricating Oil.	Distillate and Solar.	Refined.
1900	214,016	1,006,964	643,575	5,493,361
1901	140,551	915,710	1,038,867	6,814,110

Among the few companies formed during the year was the Kerosene & Lubricating Oil Co., capitalized at £500,000. This concern is the English flotation of a company already working in Russia, and is a branch of the Russian Petroleum & Liquid Fuel Co.

The exploitation of new regions has been chiefly directed to the Island of Cheleken, where some promising prospecting work has been actively carried on. The Province of Daghestan has also attracted some attention.

The development of the petroleum industry in Grosny is shown by the following figures: In 1899 the production of crude oil amounted to 25,194,566 poods, in 1900 it reached 30,400,000 poods and the production of 1901 approximates 35,000,000 poods. The Grosny industry, which is largely influenced by the Baku industry, suffered very keenly from the critical condition of the latter during the year. During the first half of 1901 the Anglo-Russian Maximoff Co. was launched with a capital of £400,000. About 30% of the output of the Grosny fields is taken by the Vladi-Caucasian Railway, and in some quarters it is believed it could establish its own markets in the northern Caucasus and on the north coast of the Caspian Sea as well as in the portion of south Russia.

The three principal English companies operating in Russia made the following outputs in 1901: The Russian Petroleum & Liquid Fuel Co., 33,291,000 poods; the Baku Russian Petroleum Co., 22,594,295 poods, and the European Petroleum Co., 16,532,991 poods.

During the year an oil pipe line from Baku to Batoum was being constructed and it is expected to be completed in about three years. The decision on the question of draining Romany Lake and its leasing out for exploitation to Russian capitalists was also a matter of moment as was also the question of the reclaiming of 300 dessatines (1 dessatine equals 2·6997 acres) of a narrow strip of sea adjoining Bebe-Aibat.

Among other items which should be referred to is the decease during the year of the inventor of mineral lubricating oils, Victor I. Ragosine; the disastrous fire at Baku, which broke out on the property of the Caspian and Black Sea Society, in which 200 lives were lost and a large quantity of oil consumed; and the striking of the large spouter by the Baku Naphtha Co. in November yielding a million poods a day which, in consequence of unpreparedness, was the cause of considerable loss instead of a source of profit; and the opening of the Petroleum Institute, in London, where a series of lectures on petroleum science and technology is delivered.

PHOSPHATE ROCK.

THE production of all varieties of phosphate rock in the United States during 1901 amounted to 1,503,623 long tons, valued at $5,336,403, as compared with 1,527,711 long tons, valued at $5,375,956, which shows a decrease of 24,088 long tons in quantity and $39,553 in value from the statistics of the preceding year.

PRODUCTION OF PHOSPHATE ROCK IN THE UNITED STATES. (*a*) (IN TONS OF 2,240 LB.)

Year.	South Carolina.	Florida.	North Carolina.	Tennessee.	Other States.	Totals.	Value.	
							Total.	Per Ton.
1897.....	333,626	543,490	7,000	121,251	2,000	1,007,367	$3,022,101	$3·00
1898.....	434,273	546,881	2,200	272,191	2,100	1,257,645	4,355,025	3·46
1899.....	476,238	706,677	15,000	462,561	3,000	1,663,476	6,350,144	3·82
1900.....	414,084	642,321	17,500	450,856	3,000	1,527,711	5,375,956	3·52
1901.....	321,181	751,996	*b* 20,000	409,653	893	1,503,623	5,336,403	3·55

(*a*) The figures for 1899 are based on railway and export shipments, except those for Tennessee, which were furnished by the Commissioner of Labor and Inspector of Mines. In 1898 and 1897 the statistics were compiled partly from shipments and partly from direct reports of the producers. In 1901 the figures are from the report of the United States Geological Survey, based on marketed product. (*b*) Low-grade rock not used for fertilizing purposes.

Prices.—Prices of Florida high-grade rock in 1901 compare with the lowest on record, notwithstanding the fact that exports were the second largest in the history of the trade. Opening in January at $7·50@$8 per long ton, f. o. b. Fernandina, prices receded later to $6·50@$7, and closed the year at $7@$7·50; making an average for 1901 of $6·83. Abroad market prices were influenced to some extent by low ocean freight rates. Consequently the c. i. f. quotations were $12·68@$13·07 per long ton in January; $10·53@$10·92 in June, and $10·53@$11·31 in December, making a yearly average of $11·45. Florida land pebble sold at $3·85@$4 per long ton, f. o. b. Fernandina during most of the year, and closed in December at $3@$3·25. Abroad prices receded from $9@$10·15 in January to $7@$8·40 in December. Florida Peace River phosphate brought $3@$3·50, f. o. b. Fernandina early in the year, then receded to $2·50@$2·75, and closed in December at $2·25@$2·50. Abroad the extreme quotations were $8·70@$6; the higher figure was realized early in the first half-year.

Tennessee high-grade rock was in good request, selling somewhat below the price quoted for Florida rock. The difference is due to the higher percentage of iron and alumina in the Tennessee product. Tennessee export rock sold at $2·50@$2·90 f. o. b. Mt. Pleasant in January, $3·25@$3·50 in June, and $3·50 in December, making a yearly average of $3·33. Abroad the c. i. f. quotations were $11·31@$11·70 in January, $10·14@$10·53 in June, and $10·53@$10·92 at the close in December, making an average for the year of $10·76. Domestic high-grade rock prices f. o. b. Mt. Pleasant were from 25 to 36c. per ton lower than those quoted on export material, and averaged for the year $2·97. The 75% grade sold at $2·50@$3 f. o. b. Mt. Pleasant, and the 70 and 72% grades at $2@$2·75.

South Carolina phosphates are consumed mostly at home, though fairly large quantities have been exported. Crude rock sold at mines at $3·50@$4 in January, $2·50@$2·75 in June, and $2·75@$3·25 in December, making a yearly average of $3·36. Dried rock brought $4·50 on vessel, Ashley river, in January, $3·25 in June, and $3·25 in December, making an average of $3·65 for the year. Abroad the c. i. f. prices opened in January at $7·80 and closed in December at $5·67@$6·30, according to destination; the year's average being $6·88. This phosphate competes with the 58 to 63% Algerian product.

Shipments.—The shipments of phosphate rock to foreign and domestic ports are given in the subjoined tables:—

SHIPMENTS OF PHOSPHATE ROCK. (IN TONS OF 2,240 LB.)

States.	1899.			1900.			1901.		
	Foreign.	Domestic.	Total.	Foreign.	Domestic.	Total.	Foreign.	Domestic	Total.
South Carolina	94,921	432,187	527,108	63,500	389,500	453,000	45,709	275,472	321.181
Florida	583,132	88,321	671,453	410,000	120,000	530,000	548,315	191,361	739,676
Tennessee.....	163,114	277,447	440,561	135,000	280,000	415,000	164,389	245,264	409,653
North Carolina....	*Nil*	15,000	15,000	.....	17,500	17,500	.....	20,000	20,000
Pennsylvania.....	*Nil.*	*Nil.*	*Nil.*	*Nil.*	1,000	1,000	.....	953	953

YEARLY SHIPMENTS OF HIGH-GRADE FLORIDA PHOSPHATE ROCK. (IN TONS OF 2,240 LB.)

Countries.	1898.	1899.	1900.	1901.	Countries.	1898.	1899.	1900.	1901.
	Tons.	Tons.	Tons.	Tons.		Tons.	Tons.	Tons.	Tons.
Austria	4,946	(c)	5,922	8,114	Italy.....	11,040	4,546	(c)	5,842
Belgium....	38,903	37,103	31,639	58,181	Norw'y & Sweden	9,378	11,938	8,000	(c)
Denmark ..	8,287	5,475	2,930	12,814	Russia	.....	1,700	2,702	(c)
England. ..	23,849	31,789	20,542	28,790	Scotland.....	6,000	9,545	1,790	6,185
France.....	.....	3,165	(c)	6,498	All other (*b*).....	3,642	8,360	6,408	6,098
Germany...	186,731	243,887	208,422	214,280					
Holland (*a*)..	64,309	87,167	54,349	72,158	Total.....	360,505	444,675	348,556	424,130
Ireland	3,420	(c)	5,852	5,175					

(*a*) A large proportion of the shipments to Rotterdam is forwarded to the interior of Germany. (*b*) Included in these shipments are those made to the United States, Australasia, Japan, Spain, and the West Indies. (*c*) Not reported.

Imports and Exports.—The total imports of phosphate rock in 1901 amounted to 174,462 long tons, valued at $868,973, as compared with 137,086 long tons, valued at $791,189 in 1900. The total exports of phosphate rock in 1901 amounted to 729,539 long tons, valued at $5,839,245, as compared with 620,070 long tons, valued at $5,217,946 in 1900. The exports of Florida high-grade rock were 424,130 long tons in 1901, as against 348,556 long tons in the preceding year.

THE WORLD'S PRODUCTION OF PHOSPHATE ROCK. (*a*) (IN METRIC TONS AND DOLLARS.)

Year.	Algeria.		Belgium. Cubic Meters.		Canada.		France.		Norway.	
1895.....	157,886	$634,323	506,730	$668,140	1,653	$9,565	526,784	$3,160,600	1,601	$23,760
1896.....	165,738	500,905	297,470	537,320	517	3,420	582,667	3,502,027	1,106	17,280
1897.....	232,141	912,564	350,056	436,702	824	3,964	535,390	2,832,887	*c* 872	12,960
1898.....	269,500	1,078,000	156,920	303,230	665	3,665	568,558	3,115,958	3,593	53,352
1899.....	324,963	1,299,852	190,090	342,180	2,722	18,000	645,868	3,334,145	1,500	22,275
1900.....	319,451	1,277,688	215,670	367,164	1,284	7,105	587,919	2,827,291	(*e*)	(*e*)

Year.	Redonda. Br. W. Indies. (*d*)		Russia. (*b*)		Spain. (*b*)		United Kingdom.		United States.	
1895.....	5,778	$24,880	6,327	$18,682	1,040	$2,061	2,540	$21,875	1,116,247	$3,296,004
1896.....	.....	.....	3,776	11,065	770	3,060	3,048	26,250	952,370	2,812,116
1897.....	812	5,525	5,917	22,132	2,084	16,672	2,032	17,500	1,022,485	3,022,101
1898.....	750	4,725	1,870	4,784	4,500	46,008	1,575	13,565	1,257,645	4,355,025
1899.....	1,507	9,250	16,863	58,640	3,510	35,100	1,469	12,645	1,663,476	6,350,144
1900.....	2,230	13,720	(*e*)	(*e*)	4,170	18,590	630	5,425	1,552,154	5,875,956

(*a*) From the official reports of the respective countries and *Annual General Reports on the Mineral Industry of the United Kingdom*, by C. Le Neve Foster. (*b*) Phosphorites exported. (*c*) Apatite exported. (*d*) Aluminum phosphate exported. (*e*) Statistics not yet published.

PROGRESS IN PHOSPHATE MINING INDUSTRY OF THE UNITED STATES DURING 1901.

BY C. G. MEMMINGER.

Arkansas.—Early in 1902 the Arkansas Phosphate Co. was constructing a large fertilizer plant on its property, on the White River Railway, which is also under construction and is being extended to the mines. The company has just commenced mining operations on a 2·5 ft. layer of 75% phosphate rock, running less than 3% in iron and aluminum.

Florida.—Florida hard rock shipments for the year were 424,130 long tons and with the exception of two small domestic cargoes, were all foreign. There was an appreciable falling off in the production of hard rock during the year, and stocks carried over at the end of the year were lower than in several years previous. In the preparation of the rock there is a marked tendency toward more careful and thorough methods, which is attained usually by the addition of one or more log washers to the ordinary double log plant; also crushing the rock after drying and subsequent dry screening give marked improved results on certain classes of rock. In fact the necessity for more thorough and careful methods of mining and preparation becomes constantly apparent, especially as the higher grade deposits become exhausted and the handling of more difficult material renders improved methods a necessity. A careful study of the entire hard rock territory makes it very apparent that the more easily mined high-grade deposits are by no means numerous and are rapidly becoming exhausted. The extreme northern section is practically exhausted, and in the extreme southern section of the district a number of deposits have been worked and the output has fallen off to a very marked extent. A positive proof of the growing scarcity of the best class of rock is that deposits are now being opened up and developed having an overburden of 25 to 30 ft. A short time ago deposits of this character were hardly classed as available. Unquestionably there is a marked limit to the supply of high-grade rock.

During the year work has been practically completed at Port Inglis, at the mouth of the Withlacoochee river, to handle this rock. It is an open roadstead, and vessels will have to be loaded by lighters. The success of this enterprise and its bearing on the movement and rates are yet to be determined.

There have been several unsuccessful efforts on the part of large producers to form a community of interests, which would undoubtedly be of great value to the miners.

Land Pebble.—There was a very marked increase in shipments of this class of rock during the year, 273,594 tons being shipped through Port Tampa; considerable shipments were in addition made to interior points of consumption by all rail, of which no records are obtainable. A new plant was under process of construction and the indications are for a still further increase of production during 1902.

The application of electricity for the distribution of power in one of the largest and best appointed plants in the district presents a rather novel feature in this class of mining. The economy of this system is yet to be proven, although it has many admirable features. The question of fuel supply continues to become more serious in this district, as the supply of wood easily available for the plants is fast becoming exhausted. Texas oil will be adopted as fuel by at least one plant, and may in a measure tend to solve this problem, but as the fuel forms so large a part of the production cost of this class of rock, price of production must gradually increase with increased fuel cost.

A few new deposits of considerable extent have been developed during the year, and there are now large reserves of this class of rock in this district, especially of grades running from 65 to 67% of bone phosphate and from 3 to 5% of iron and aluminum oxides combined.

River Pebble.—The shipments of this class of pebble for the year amounted to 46,813 tons, distributed as follows: Domestic, 28,023; foreign, 18,790 tons. There is nothing of special interest in regard to this class of rock.

North Carolina.—The shell rock quarry at Castle Haynes, N. C., has been operated for the past two years, although the city of Wilmington is taking the entire output for macadamizing the streets. The estimated quantity of material produced in 1901 was 20,000 long tons, as compared with 15,000 long tons in 1900. These quantities have not been included in the tables of production as the rock, which is of extremely low grade, is not used for fertilizing purposes.

Tennessee.—In the Mount Pleasant district the Tennessee Phosphate Co. has been merged with the Federal Chemical Fertilizer Co. It is to be presumed that this company will consume its own rock output and that but little if any will be available for the market. This company, which was one of the principal producers during 1901, has completed a fertilizer plant on the Nashville, Chattanooga & St. Louis Railroad, 4 miles from Nashville. The buildings cover 99,000 sq. ft. of surface, and have a storage capacity of 30,000 tons. The acid plant is to have the latest improvements, and is to be built so that it can be increased as the demand for fertilizers increases. The fertilizer plant is to be equipped with the latest improved machinery, and embodies some improved

methods of handling the fertilizers. The grounds cover 15 acres, and an extensive trackage system is being installed.

The Virginia-Carolina Chemical Co., already holding large properties in this field, is expected to increase them. The absorption of the mines by the large fertilizer companies, if continued, will result in very little of this class of rock being available for the open market. The limits and possibilities of the Mount Pleasant field are well known, and while there will probably be some extension of the field, the discovery of large bodies of high-grade rock is not probable. Mining of the brown and blue rock in Hickman County continues on a small scale. This rock forms an excellent basis for the manufacture of superphosphates. There are large reserves of this rock in Lewis and Hickman counties, but the best and most available deposits are either controlled or owned by the large fertilizer companies. No development of any extent has been done in the white phosphate deposits of Perry County. There is some mining and reports of new finds in several counties of middle Tennessee, but no deposits of important commercial value have been developed.

South Carolina.—The bulk of the land rock deposits is owned by the Virginia-Carolina Chemical Co., and the rock is mined for its own consumption. The Coosaw Co., one of the landmarks in South Carolina river rock phosphate mining, has ceased operation and will dispose of its entire mining plant and retire from the business. There is still some river mining being carried on, but on a restricted scale.

Summary.—A special feature of interest to be noted during the year is the marked tendency on part of the larger consumers of crude phosphate to secure their own sources of supply. There is also a marked increase in the number of independent fertilizer factories—independent of the so-called fertilizer trusts. Unquestionably there is a very decided increase in consumption of commercial fertilizers, which is especially noted through the Middle States, where lands formerly very fertile now require to be fertilized. Despite the increase in consumption of fertilizer there has been, without apparent reason, a decline in prices of both Florida high-grade and pebble rock, a condition which is certainly abnormal.

Phosphate Mining in Foreign Countries.

Algeria.—Due to the decree of 1898, the combine of all the leading producers now operating the phosphate beds at Tocquville, Ainkissa, Dyr and Kouif practically have control of the phosphate mining in Algeria and it is questioned whether any extension of the business will result under the present conditions. The following companies were operative during 1901: The Constantine Phosphate Co., Le Société des Phosphates, de Tébessá, Le Société Française des Phosphates de Tocqueville, Crookstons Bros., Hebre & Girault, Argin Kemna Co., and Société Generale des Mines. The factory erected near Bona has been in operation since 1899, the sulphuric acid used being obtained by the treatment of pyrites from Portugal. The products have been sold mostly in the colony, especially for vineyard culture. The shipments of phosphate from Souk-Ahras during 1901 amounted to 226,690 metric tons, apportioned as follows: Compagnie des Phos-

phates du Cyr, 88,440; Mine de Kouif, 103,600; La Société Française des Phosphates de Tocqueville, 32,880; Mine de Aiu Kerma, 1,770 metric tons. The product from the Kouif mine, operated by the Constantine Phosphate Co., is reported to be of the following composition: P_2O_5 31·52% (=$Ca_3P_2O_8$ 68·71%), CO_2 8·5%, SO_3 2·78% (=$CaSO_4$ 4·73%), $CaCO_3$ 50·77%, MgO 0·62%, Fe_2O_3 and Al_2O_3 0·85%, combined H_2O 2·35%, organic matter 2·33%, insoluble 0·38%. Five cargoes of phosphate rock from the Kouif mine, operated by the Constantine Phosphate Co., were reported of the following compositions:—

Cargo.	Water.	Tribasic Phosphate of Calcium.	Calcium Carbonate.	Silica.	Iron and Aluminum Oxide.	Gangue.	Calcium Sulphate.	Magnesium Oxide.	Organic Material and Alkalies.
	%	%	%	%	%	%	%	%	%
1st.....	2·35	68·71	17·77	0·38	0·85	.....	4·73	0·62	....
2d.....	2·77	68·84	16·52	0·40	0·39	5·16	4·02	1·10	5·80
3d.....	2·29	65·43	15·45	0·40	0·25	4·30	3·69	0·35	7·84
4th.....	2·98	65·33	13·77	0·43	0·36	4·25	3·70	0·88	8·20

High-grade phosphate rock from the Debba mine, operated by the Société Française des Phosphates de Tébessá, analyzed P_2O_5 31·3% (=$Ca_3P_2O_8$ 68·27%) and $CaCO_3$ 17·34%, while that of the second quality was P_2O_5 28·42% (=$Ca_3P_2O_8$ 62·04%) and $CaCO_3$ 19·98%.

Christmas Island.—The phosphate deposits are reported to contain 86% calcium phosphate, and in addition to the 12-in. layer on the surface of the island which alone was worked during 1901, a second deposit occurs from 5 to 6 ft. below the surface. In other places prospect pits 40 ft. deep have failed to find the bottom of the deposit. Mining operations are carried on by 700 Chinese coolies, who load the surface material into small iron trolleys extending in as many directions as desired, which are lowered down the hillside by a wire rope and drum on iron rails to the tipping shoot, from whence it is loaded into trucks and tipped into the lighters of from 0·5 to 0·75 ton capacity. The lighters are worked to the vessels and unloaded by hand—a laborious and tedious operation. During 1900 and 1901 there were 12,000 tons of phosphate shipped from Christmas Island to Japan, and it was estimated that the total shipments during 1901 aggregated 37,000 tons.

Egypt.—A discovery of phosphate rock was reported in the region adjacent to the Jorclan river which it is thought will be developed as soon as better means of transportation are at hand.

France.—During 1900 the production of phosphate rock in France, amounting to 587,919 metric tons, was exceeded only by that of the United States, which was 1,663,476 metric tons. These two countries contributed 80% of the world's output for 1900. The progress in opening up the recently discovered deposits in the Pyrenees Mountains is briefly summarized as follows: The Saint-Gobain Co. has opened several phosphate quarries in the Artillac Valley, between St. Giron and Foix, where the Devonian schistose deposit of from 2 m. to 12 m. in thickness has been almost entirely replaced by nodules of phosphate rock. The rich deposits of Tarteing Milles and Cazalos are also being developed. The Lyons Co. has built a factory at La Bastide de Seron to treat the product from its mines at Rimont, Las Caleses, and Larblont; other mines will be opened up at the

completion of the Saint Girons a Foix Railway. The phosphates deposits of this region are generally associated with manganese ores; in fact the discovery of the phosphate rock was first made at the manganese mine at Las Caleses. The Signat mines contain a slight proportion of nodular phosphate of 70 to 75% richness in schists which yield from 30 to 35%. The mine is favorably located 4 km. from Marignac station. Several quarries are being operated near Accons, on the right bank of the Gave de Lescum river. The deposit of phosphate varying from 1·5 m. to 7 m. in thickness, is free from nodules, although on the left bank nodules are found. The Pyrenean phosphates may be divided into (1) The Basses Pyrenees group, Valley of Lescum, (2) The Central group, Valleys of Luchon and Oueil, and (3) The Ariege group, Valleys of Estangue, Artillac and Arize. It is expected that at the completion of the Saint Girons a Foix Railroad the Ariege group will contribute largely to the output, and it is estimated that the cost of nodules per ton at Castelnau, Durban or Rimont will not exceed 28 fr. per ton.

Norway.—The Dahls mine, near Ödegaarden yielded 1,100 tons of apatite in 1900, and the French company operating in the same district recommenced work toward the end of the year. The price for the best apatite during 1900 averaged $18 per ton at Norwegian ports.

Russia.—Owing to the rapid development of the beet sugar industry there has been a large increase in the consumption of superphosphate as fertilizer. The Russian manufacturers, however, of which there are five at present, are able to supply only a small part of the demand, large amounts being imported each year from Germany and other countries. Phosphate rock is mined in the Province of Podolia, on the Dniester river, but the output is small and is supplemented by imports of rock from the United States.

South Australia.—New discoveries of phosphate rock were made in the north-eastern part of Yorke peninsula, about 2·5 miles from the port of Clinton. An analysis of specimens from this locality showed 34·56% P_2O_5, corresponding to 75·4% tircalcium phosphate.

Tunis.—A company has obtained a concession at Metlaoui for 60 years of an area of 193 square miles, and a railway has been constructed from the oasis of Gafsa to the mines, a distance of about 28·5 miles, as well as one to the sea coast. The company pays to the State a royalty of 20c. per ton of phosphate up to a total of $30,000 per annum, after which the royalty on the next 100,000 tons is diminished by 7c. per ton, with a still further reduction beyond this quantity. There are four principal beds, one of 13 ft. in thickness, the next of 6 ft., and the two lower beds of a thickness from 5 to 6 ft. 6 in. The beds contain from 59 to 61% of tribasic calcic-phosphate. There were 1,300 work-people employed on the mine and railway during 1900. The phosphate f. o. b. mines does not cost more than $1 per ton. It is stated that providing the annual output is 300,000 tons, the total cost at the port of Sfax of the marketable phosphate will be only $2 per ton.

The Phosphate Deposits of Ocean and Pleasant Islands, in the South Pacific.

By F. Danvers Power.

Banaba, or Paanopa, commonly known as Ocean Island, is classed as one of the Gilbert Group, thus coming under British influence, while Nauru, or Pleasant Island, is classed in the Marshall Group, and is under German control.

Ocean Island has an area of 1,389 acres, and, like Pleasant Island, somewhat resembles the shape of a kidney in plan. The nearest land is Pleasant Island, 160 miles distant. Neither of these islands naturally belongs to any group, but together with others are known as the "Line Islands." They are raised coral islands and are surrounded by a nearly level shore reef some 100 yd. wide. At the edge the land drops very steeply below the ocean—about 400 ft. in 170 yd. Ocean Island is surrounded by cliffs of coral rock from 12 to 30 ft. high, which are broken up into pinnacles by two series of gullies about 6 ft. wide; one series has a contour similar to that of the island, while the other, at right angles to the former, corresponds more to the boat passages at the edge of the shore reef. From these cliffs the land gradually rises to a height of 260 ft., the center of the island being practically flat. There is no trace of a lagoon to be seen on the island, and if one formerly existed it must have become subsequently filled up and its rim leveled.

The physical features of Pleasant Island, which has an area of 4,692 acres, are somewhat different from Ocean Island. Inland from the shore reef, which is covered at every high tide by about 4 ft. of water, is a cocoanut belt, averaging 100 yd. wide, which is really a continuation of the shore reef, but at a higher elevation on account of having been covered with coral sand washed upon it in banks during storms. On the island side of the cocoanut belt the ground rises suddenly forming a wall of coral pinnacles similar to those surrounding Ocean Island. At the southwestern end of the island, inside the wall, is an oval-shaped range of hills enclosing a lagoon, and from the south of this range a second range passes around the northeast side of it, joining it again at the north. There are occasional passes through these ranges, and occasional peaks on the higher land up to 220 ft. above the sea level. The ground between the ranges is low, while the lagoon is nearly at the same level as the sea. There are other lower ranges trending across the island inside the wall of pinnacles from northwest to southeast.

Inside the outer wall of both islands is covered with lime phosphate of a remarkably uniform and high grade. There is very little soil and the stripping of a few inches removes practically all the organic matter. The phosphate deposits of these islands are controlled by the Pacific Island Co., of London and Sydney, and the good quality of the phosphate, together with the exceptional facilities for mining this material, gives advantages which enables the company to command the Australasian and New Zealand markets.

The phosphate rock is divided into two kinds, classed for commercial purposes: (1) "alluvial," which is in loose grains 0·3 in. and less in diameter, and (2) "rock," which includes loose pieces over 0·3 in. in diameter, also massive blocks

found *in situ*. The classification is merely one of size and not of origin, which was made for the benefit of buyers, some of whom are not provided with coarse crushing appliances.

Geologically there are four kinds of rock: (1) Primary rock, formed and brought into position by chemical means. (2) Primary alluvial, broken up and deposited in its present position by mechanical means. (3) Secondary rock, and (4) Secondary alluvial. There may be ternary and quaternary rock and alluvial, but it is impossible to determine them. However, the original and secondary forms are of interest, as they prove that the island has been raised at least three times and lowered twice, facts which under the circumstances are not easy to demonstrate by other means.

Years ago when these islands were comparatively barren and probably uninhabited, sea birds undoubtedly used them as breeding and depositing grounds. The fish abounding in the neighborhood of the islands supplied them with food and the excess of phosphorus was passed away with their droppings. The bulk of these droppings is enormous, on islands near the Peruvian coast guano deposits having been found 195 ft. thick. The soluble phosphate was leached out of the guano by rain, sea spray and dew, and coming in contact with the underlying coral rock took up the necessary lime to satisfy it, thus becoming fixed as phosphorite, which then collected in joints and other cavities in the rock. At the present time similar phosphate deposits can be seen either filling the joints completely or in layers on either wall. That it has filled in from above is shown by the stalactitic forms it assumes in certain cavities. To prove that the phosphoric acid acted on the coral rock, some of the buried pinnacles unearthed by mining operations have a jacket of lime phosphate, about 0·5 in. thick, underneath which the coral rock has a smooth surface. The phosphate is also found forming interior casts of shells and corals.

In course of time the island sank slightly, and the coral rock, together with the phosphate, became worn down by wave action. The former being more friable and soluble than the phosphate, was broken up into smaller pieces and removed, while the tougher and comparatively insoluble lime phosphate was concentrated in caves and passages (original or weathered, so common in coral islands) in the form of sand and waterworn pebbles, thus forming the primary alluvial phosphate. As the land rose again the phosphate, which was leached from fresh quantities of guano, filtered through to the spaces occupied by the alluvial phosphate and cemented it into a compact body, forming the secondary rock phosphate. Deposits of this type can be seen filling former cavities and possessing a very pretty pisolitic appearance. Again the land was lowered and the rock subjected to disintegration as before. This time, besides primary alluvial, there resulted some secondary alluvial which was formed by the breaking up and rolling about of the secondary rock phosphate. Waterworn composite pebbles of this nature are to be found in the interior of both islands. In the alluvial phosphate are recognized particles that have been deposited under different conditions, *i.e.*, those deposited in joints and those deposited on the floors of the caves. When consolidated these are often mixed up together in a confusion of shapes and sizes, which indicates that they had been stirred up with considerable force.

The action of the sea seems to have had a greater effect on the disintegraion of coral rock than that of atmospheric agencies. The sea has cut back the island while forming the shore reef, as is indicated by the caves hollowed out at the foot of the cliffs by the waves. These caves and other passages, whether formed by the building up or the breaking down of the islands, are important, as they form a lodgment for the alluvial deposits. Inland, at the foot of those pinnacles which appear above the surface very little if any detritus of lime carbonate is to be seen even though the material is dug out at the base. This is so general that the natives invariably used blocks of rock phosphate to build the walls surrounding their different properties. This lack of fragments of limestone mixed with the alluvial phosphate causes the latter to be clean so there is no occasion to wash it. A sharp line of demarcation exists between the rock phosphate and the coral rock. The deepest hole sunk on Ocean Island is 29 ft., which does not penetrate through the deposit. The higher pinnacles are 30 ft. above the ground where the material between them has been washed away. The depth of the deposit in the center of the island is unknown, though the holes sunk in various places are sufficient to show that there are immense available deposits of high-grade phosphate. On the tableland at Ocean Island are several shallow depressions which probably indicate the presence of primary rock phosphate deposited in cavities of the coral rock, the limestone having been dissolved out and probably causing a slight local subsidence; at all events, wherever holes are sunk in these places, cavernous rock phosphate has been found, and in other places natural holes or native wells have shown a similar condition.

The following analysis by Mr. A. E. Stephen, of Sydney, of a 3,000-ton shipment from Ocean Island is a fair average of the material. It is calculated on the dry basis. The moisture naturally varies with the weather, but it is generally dried in the sun to 1%. CaO 53·83%, Fe_2O_3 and Al_2O_3 0·46%, P_2O_5 40·3% (=$Ca_3P_2O_8$ 87·97%), CO_2 1·5% (=$CaCO_3$ 3·41%), SiO_2 0·06%, SO_3, MgO, K_2O, Na_2O 1·54%, organic matter and combined water 2·31%, total 100%.

The sulphuric acid varies between 0·5% and 0·75%, the magnesia is about 0·75%, while the silica is between 0·1% and 0·2%. Special picked samples have yielded as high as 93% of tribasic phosphate.

An analysis of Pleasant Island phosphate dried at 100° also made by Mr. Stephen gave: CaO 52·94%, Fe_2O_3 and Al_2O_3 0·51%, P_2O_5 39·86% (=$Ca_3P_2O_8$ 87·01%), CO_2 1·5% (=$CaCO_3$ 3·42%), SiO_2 0·1%, SO_3, MgO, K_2O, Na_2O 2·43%, organic matter and combined water 2·66%, total 100%.

As is always the case in phosphate analysis, there is an excess of lime over the acids present that are capable of combining with it. This excess is supposed to be in organic combination.

PLATINUM AND IRIDIUM.

THE production of platinum from domestic ores in the United States during 1901 amounted to 1,408 oz., valued at $27,526, as compared with 400 oz., valued at $2,500 in 1900. This notable increase in production, however, does not begin to supply the United States' demand, the total domestic output being but a very small proportion of the consumption. The production during 1901 was the largest quantity recorded since 1880, the year in which statistics of platinum produced from domestic ores were first compiled. The next largest output was in 1890, when 600 oz., valued at $2,500, were produced. In connection with the production of platinum from domestic ores during 1901 there were obtained also 253 oz. of iridium, a metal so closely allied to platinum in its properties that doubtless it has formed from 15 to 25% of the reported platinum production in former years.

The chief sources of the domestic supply of platinum are gold placer deposits in Trinity and Shasta counties, Cal., from which the metal is obtained as a secondary product. Platinum occurs also in many other gold placers of California, as well as in Washington, Oregon, Idaho, Montana, and Alaska, but the deposits have not been sufficiently rich to place the extraction of the metal on a profitable basis.

The most noteworthy feature of the platinum industry in the United States during 1901 was the discovery of the metal in the form of sperrylite in the copper ores of the Rambler mine, near Encampment, Albany County, Wyo. Other metals of the platinum group—osmium, palladium, and iridium—were also present, although they were not distributed uniformly throughout the ore, some samples showing palladium and others platinum only. In most cases, however, all four metals were found. The platinum content of the ore varied from 0·06 oz. to 1·4 oz. per ton, and in a selected sample of covellite (CuS) it was as high as 12 oz. The platinum occurs as sperrylite, and in all probability palladium also will be found as an arsenic compound. As a result of this discovery it is important to examine all copper ores for metals of the platinum group; so far, the residues from the electrolytic process in a few of the largest copper refineries have failed to show the presence of the metal.

Other new discoveries of platinum in place which were reported during 1901 are: In peridotite in the Similkameen district, B. C.; traces in serpentine near Weaverville, and near Junction City, Trinity County, Cal.; near Kirby, Josephine County, Ore., and chalcopyrite containing platinum and nickel has been reported as occurring near Bunkerville, in southeastern Nevada.

Samples of rock submitted for analysis by J. C. Carter, of Leavenworth, Wash., contained 0·375 oz. of platinum metals to the ton, and finer material from the same locality contains 0·5 oz. Pt to the ton of ore.

A new discovery of sperrylite, the platinum arsenide mineral, has been reported in the sands of Cowee Creek, Macon County, N. C., where it occurs in minute quantities, but there has been no authentic record of the occurrence of metallic platinum in the Eastern or Southern States.

It is of interest to note that chromite is nearly always associated with platinum, and occurs in the extensive serpentine formations of many mountain ranges in which streams have their source, and in all deposits containing platinum in place, the metal occurs with chromite disseminated through basic magnesium rock of which serpentine is a common alteration product. It has been forecast as within the range of probability that platinum will be found in place associated with chromite in the basic magnesium rocks of California and Oregon as well as in the basic magnesium rock peridotite of North Carolina, Georgia, Pennsylvania and Maryland, which frequently contains chromite. It is to be hoped that future discoveries of platinum will be made which will tend to alleviate the present threatened dearth of this important metal. Chrome ore deposits also should be examined carefully for platinum, as this mineral occurs to a considerable extent in the American platinum as the mineral is its most common associate. The discovery of a use for the osmium which osmiridium, will greatly benefit the platinum industry of the United States; as in the past this mineral has interfered most seriously with the sale of the crude domestic product. The demand for osmium for the new Auer incandescent electric light makes it almost as desirable as platinum.

The world's annual production of platinum for the past few years has ranged between 160,000 and 170,000 oz., of which, as far as can be ascertained, Russia supplies at least 150,000 oz., the balance being obtained from South America.

Imports.—The imports of platinum during 1901 were valued at $1,673,713, as compared with $1,728,777 in 1900, which shows how insignificant is the domestic supply of this important metal.

Market.—The pure platinum content of platinum sands has ranged during 1901 from $18 to $22 per oz. New York quotations for the ingot metal per Troy oz. remained at $18·20 from the beginning of the year until May 11, thence until the close of the year it ruled at $20·50, and during October, November, and December the price was from $20 to $21 per oz., closing the year at the latter figure. Osmiridium is given at from $6 to $10 per oz. The price for hammered platinum in quantity varied from 80c. to 82c. per g. during the year, closing at the higher figure.

Canada.—A company was formed early in 1902 to develop the platinum claims of 320 acres on Slate creek, just over the divide of the Similkameen

river, on the Washington side. Operations will also be extended into British Columbia territory. Reported assays of the gravel give a value of 25c. per cu. yd., the precious metal content being 66% gold and 34% platinum. Another deposit of platinum is also reported in Kennedy Mountain, near Princeton. The Government assayer at Vancouver, B. C., reports finding considerable platinum in the gold dust from the Klondike received during 1901. Platinum has also been reported with gold in commercial quantities in a quartz vein on a small island in the Lake of the Woods, some 12 miles from the town of Rat Portage, where a pit has been sunk to sample the deposit.

Russia.—The production of platinum in the Urals from 1891 to 1900 is given in the subjoined table:—

Year.	Poods.	Oz. Troy.	Year.	Poods.	Oz. Troy.	Year.	Poods.	Oz. Troy.
1891.....	258	135,874	1895.....	269	141,668	1899.....	368	191,172
1892.....	279	146,934	1896.....	301	158,520	1900.....	332	174,846
1893.....	311	163,787	1897.....	345	181,698	1901.....	380	200,260
1894.....	318	167,478	1898.....	365	192,225			

The new Platinum Industrial Co., which bought up a group of the most productive platinum mines and expected to produce an annual yield of 130 poods, reported only 50 poods in 1900.

New South Wales.—The production of platinum in New South Wales in 1900 was 530 oz., valued at £1,007, which was obtained chiefly from the Fifield district, about 322 miles west of Sydney, where it is found associated with gold. A deep alluvial "lead" containing the two metals extends for over a mile, varying in width from 60 to 150 ft. The sinking is from 60 to 70 ft., through loam, with some bands of barren quartz drift. The platinum and gold occur in fairly coarse waterworn grains, which are generally confined to the cavities in the bed-rock, and to the wash-dirt for a few inches above it, the latter containing from 5 to 12 dwt. of platinum and from 1 to 3 dwt. of gold per ton. The yield from 269 loads, taken from a number of claims along the "lead," was at the rate of 6 dwt. 21 gr. of platinum and 1 dwt. 23 gr. of gold per ton.

Norway.—An extensive platinum-bearing deposit was discovered during the summer of 1901 in the vicinity of Arendal, and a 10-ton experimental plant was erected to test the commercial value of the ore.

TECHNOLOGY.

Electrodes.—A new form of platinum electrode has been invented by Heraeus,[1] consisting of a thin glass tube closed at the lower end, having a number of platinum wires fused into the walls; the projecting ends of the wires are fused to platinum stripes 0·8 in. wide and 0·0003 in. thick, and the inner ends are soldered to an equal number of copper wires attached to a copper block for the electrical connection; 100 g. platinum suffices for 10·75 sq. ft. electrode surface. It is claimed that this new form of electrode can compete in cheapness with carbon.

Heraeus[2] tested platinum-iridium electrodes for chemical restivity in electrolysis alkaline chlorides, and found that with an alloy of platinum of

[1] *Elektrochemie*, September, 1901.

[2] *Zeitschrift fuer Elektrochemie*, March 6, 1902.

from 7·6 to 15% iridium, an electrode could be rolled to a thickness of 0·007 mm. and yet have sufficient chemical resistivity to be used on an industrial scale.

Recovery from Waste Solutions.—Adolf Berthold[3] proposes the following method for the recovery of platinum from waste solutions. The solution holding the platinum salts is first filtered to remove any platinum sponge that may have been formed, the latter being dissolved in aqua regia and the solution boiled to expel nitric acid. The two solutions are then combined and barium chloride added to remove sulphuric acid, after which the platinum salts may be reduced by treating with concentrated hydrochloric acid and metallic zinc. If a precipitate of potassium-platinic chloride should form during the reduction process, the solution must be heated and any alcohol or ether present driven off. The platinum sponge is removed by decantation and subjected to boiling with hydrochloric acid and to repeated washings with water until all traces of chlorine are removed. A final filtration through a Gooch crucible is to be recommended. In place of the zinc precipitation method, the author believes that the recovery might be effected satisfactorily by electrolysis.

Analytical Determination of Platinum and Iridium.—Leidié and Quennessen[4] determine platinum and iridium in platinum ores by repeatedly extracting 5 g. of sample with hot aqua regia until complete solution. The united extracts are evaporated to dryness at 105 to 110°C., and the residue taken up with a little water and filtered. The filtrate is heated to 70°C., sodium nitrite is added until the liquid is neutral to turmeric, then sodium carbonate to complete precipitation. The liquid is then heated to the boiling point, and filtered to separate foreign metals from metals of the platinum group. The filtrate is rendered alkaline with NaOH and Cl passed through at a temperature of from 70 to 80°C. to expel as osmium and ruthenium volatile peroxides. The liquid is now neutralized with HCl, and more $NaNO_2$ added to reconvert into nitrites any chlorides of the other metals. In addition to the alkali salts there will now only be present the double nitrites of sodium with platinum, palladium, iridium, and rhodium.

To determine the platinum from 30 to 35% KCl is added, which precipitates rhodium and iridium as double nitrites with potassium. Filter the converted platinum and palladium nitrites into chlorides by means of hydrochloric acid, the saline mass being finally taken up with boiling water. The solution is boiled with a slight excess of formaldehyde, which precipitates the two metals in the metallic form. The precipitate is collected, ignited, reduced in a current of hydrogen, and dissolved in aqua regia. This solution is evaporated, the residue taken up with water and reduced to convert palladic chloride into palladous chloride, the platinum is then precipitated with NH_4Cl, and determined by the usual methods.

To determine iridium, the liquid from which the osmium and ruthenium have been expelled is divided into two parts, one being reserved for the determination of the platinum as described above. In the other the double nitrites of rhodium and iridium are converted into chlorides by means of aqua regia containing but little HNO_3. The iridium is precipitated by NH_4Cl in the form of a chloro-

[3] *Zeitschrift fuer Angewandte Chemie*, June 18, 1901. [4] *Journal Pharm. Chim.*, 1901, 351-355.

iridate, the precipitate washed with a solution of NH_4Cl, ignited, reduced in hydrogen, and weighed as metallic iridium. The iridium could also be precipitated with potassium chloride in the form of the double chloride, $IrCl_4 \cdot 2KCl$, the addition of a little water accelerating the precipitation. Finally the reduced product is washed with water to remove the KCl, and dried at 115°C. This method gives the available iridium only, or that which is in combination with the platinum or other metals, and so dissolves in aqua regia. Any iridium in the free state or combined with the osmium is insoluble, and remains undetermined in the extracted residue.

H. W. Wiley[5] reduced platium from the hot aqueous solution of potassium-platinic chloride by the addition of aluminum wire or clippings. Hydrochloric acid is added to aid the settling and to dissolve excess of aluminum; the settled platinum is washed by decantation until the complete removal of chloride, the solution being filtered, if necessary, to regain any platinum suspended therein. The spongy platinum residue is heated with nitric acid to remove any copper present and the remaining platinum block is washed, dissolved in aqua regia, evaporated on steam bath until a portion taken on a glass rod solidifies. Water is then added and the solution re-evaporated until nitrous fumes cease to form on the addition of water. The resultant solution of platinic chloride is then ready to be diluted to required strength.

NOTES ON PLATINUM AND ITS ASSOCIATED METALS.

BY JAMES F. KEMP.

THE price of platinum has steadily augmented within recent years until now its quotations exceed those of gold. Special interest therefore is attached to its occurrence in nature and above all to its presence in the situations and associations which have not hitherto attracted all the attention that they have deserved. The properties of platinum are altogether exceptional and render it available for scientific and commercial processes for which there seems to be no suitable substitute. These special uses are likely to increase rather than decrease, and therefore, aside from the fact that manipulation and control of the markets may have in some degree caused the increased price, yet the latter is based in part on the actual demand for the metal.

I became interested in the subject while making investigations for the S. S. White Dental Manufacturing Co., and in association with Mr. Albert W. Johnston, to whom acknowledgments are due for the generous permission to use much of the following information.[1]

Almost all the platinum of commerce is obtained from placers and by hydraulic processes. The metal is generally described as occurring in the native state, but this is only partially true. The richest nugget yet assayed and recorded yielded 86·50% Pt. The greater number range between 85 and 70%, and not a few go lower still. Much the most abundant of the other metals, which appear in the nuggets, is iron. When all the available assays are plotted

[5] *Journal of the American Chemical Society*, January, 1897.

[1] A more extended treatment of the subject will be found in *Bulletin* 108 of the United States Geological Survey.

it is found that iron gradually increases as the platinum percentage falls, until the latter reaches about 69%. The highest iron percentage of which I know is 19·5% with 68·8% Pt in a specimen from the Urals. Iron then rapidly decreases with the increase of platinum and with values below 80% Pt, iridium tends to become very abundant. As a rule the other metals of the platinum group, *viz.*: iridium, rhodium, and palladium are always present. Until the platinum falls below 60% the iridium seldom reaches 5%; rhodium seldom reaches 4%, and palladium is less than 2%. In the curves which I have plotted, however, there seems to be no law governing their relations. The above statements it should be further remarked are based upon analyses of what would be mineralogically described as platinum and do not include the other mineralogical species. Besides the associated metals just referred to, the nuggets often contain osmium, ruthenium, copper, and sometimes even gold, but the percentages are smaller.

In the way of mechanical admixture chromite is the commonest associated mineral, some nuggets showing a large proportion of it. Much more rarely olivine adheres to the platinum, as do also rarer silicates, such as biotite and pyroxene. Scales of iridosmine have been obtained by dissolving away the more soluble platinum.

Besides platinum the other minerals which contain the metals of this group are the following:- Platiniridium, palladium, allopalladium, and iridosmine (sometimes called osmiridium). There are two compounds with non-metals, sperrylite ($PtAs_2$), and laurite (RuS_2). In laurite a little osmium replaces a part of the ruthenium. Of these minerals only iridosmine and sperrylite are of any commercial importance. The former has been vigorously sought in recent years because of its osmium, which is much desired on account of its incandescent properties. Sperrylite as an associate of the nickel-copper ores at Sudbury, Ont., and in the Rambler copper mine, Wyoming, is of more than purely scientific interest.

In its usual associations platinum is found only with the basic, igneous rocks which are rich in the mineral olivine, or chrysolite. They constitute the group of the peridotites and are likewise the home of chromite, the commonest associate of platinum. The peridotites change readily under metamorphosing influences to serpentine, and it is therefore not surprising to find that the platinum is often traceable to this mother rock.

As stated above, the platinum of commerce is still almost exclusively obtained from placers and yet the actual gravels seldom rest upon peridotites. It is necessary to follow the streams to their upper portions, in order to locate the mother-rock, but then, so far as known, the peridotites or their relatives are always discovered. In the Tura river region of the western Urals, for example, the bed-rock of placers is Devonian limestone but the source of the platinum is in the peridotites up-stream.

In one of two instances in the Urals and in several cases in the Tulameen river district of British Columbia, the platinum has been detected by assay in the peridotite or in its derived serpentine, but the amounts have proved to be so small, or else the metal has been so irregularly distributed, as not to present

an economic proposition. The evidence in hand leads to the conclusion that the platinum is very sparsely disseminated.

Platinum is also found in other rocks. It has been detected in pyroxenites and even in crushed and chloritized granite in the Tulameen region. It has likewise been reported elsewhere from syenites and gabbros. Mr. A. W. Johnston has determined it by assay in hornblende gneiss and Triassic shale from Pennsylvania. In the shale it may have been in the form of a fossil placer. The late Dr. F. A. Genth, of Philadelphia, detected it in a clay slate from Lancaster County, Pa., which contained pyrite, chalcopyrite and galena. He also found it in ilmenite in a mica schist from the same place.[2] In a most extraordinary deposit near Broken Hills, New South Wales, it has been found in kaolinized material, lying beneath an iron cap, and shading into less and less altered granite or gneiss in depth. It is supposed by Mr. J. B. Jaquet,[3] who has described the occurrences, that the vein phenomena were produced by an uprising hot spring. The region is one of metamorphosed Lower Silurian strata, in which are dikes and bosses of granite.

Platinum has been reported in several instances, and on good authority, as occurring in gold-bearing veins, and in such a way as to lead one to believe that so far from being associated with basic igneous rocks, it was actually in a gangue of quartz. C. F. Hartt, in his work on the "Geology and Physical Geography of Brazil," page 448, quotes from E. Williamson,[4] who states that platinum occurs with the usual common metallic sulphides, in the gold quartz vein called Boa Esperanca, in the Province of Parahyba do Norte, Brazil. Palladium has likewise been known for many years at Gongo Seco, in the Province of Minas Geraes, and a variety of gold called "ouro preto" has received a special name, apparently because of this. Hartt in a footnote of the work just cited, page 542, states that the Brazilian gold is occasionally alloyed with platina. Platinum has also been reported from the gold quartz veins of the Beresovsk[5] district, Russia. In a sample from Leavenworth, Wash., which the microscope proves to be a vein of crushed quartz with much pyrite, A. W. Johnston and myself have found 0·375 oz. to the ton.

The allopalladium of the treatises on mineralogy was obtained in association with gold in veins of red hematite in diabase, at Tilkerode, Hartz Mountain.

The most interesting and, commercially speaking, the most important association of platinum is with copper-bearing minerals. Several such cases have long been matters of record, although they have been mostly overlooked. It is a strange fact that platinum was recorded from Spain, by the French chemist Vauquelin as early as 1806, while there existed only unconfirmer rumors about the Urals. Vauquelin reports it in amounts varying from traces up to 10% in a silver ore from Gaudalcanal. The ore contained in addition copper, lead, antimony, iron, sulphur, and sometimes arsenic. It occurred in a gangue of

[2] *Pharmaceutisches Centralblatt*, 1852, 72.

[3] J. B. Jaquet, *Records* of the Geological Survey of New South Wales, V., 1896, p. 33.

[4] E. Williamson's paper, of whose volume and page Prof. Hartt did not know, is from the *Transactions of the Geological Society*, of Manchester, Eng., VII., 113, 1866.

[5] Phillips-Louis, *Ore Deposits*, p. 546.

calcite, barite and quartz,[6] and was considered to be a variety of tetrahedrite. A French mining engineer named E. Gueymard identified platinum in a tetrahedrite from the French Alps as early as 1847. The ore occurred in the valley of Drac in beds of crystalline limestone, in association with dolomite, quartz and barite. The other metals present were copper, antimony, lead, zinc, iron and a little arsenic. In 100 assays, 20 gave either traces or weighable amounts. M. Gueymard afterward found platinum in similar associations in several other localities in this same general region, and once in bournonite. His results were fully confirmed by the best chemists of Paris.[7]

The discovery by F. L. Sperry of a heavy metallic residue in the concentrates of the Vermillion mine, near Sudbury, Ont., and its subsequent identification and description as sperrylite ($PtAs_2$) by Professors Wells and Penfield,[8] first called attention to the existence of platinum in connection with the nickel-copper deposits of this region, and although it was first observed in the concentrates of a stamp mill working for gold, it has since been observed in the base metal ores. Indeed, Clarke and Catlett[9] subsequently determined platinum in quantities respectively of 2·55 oz., 1·8 oz., and 7 oz. per ton in polydymite from Sudbury. The metal received attention as a possible by-product in treating the mattes.

The most interesting announcement in this connection which has appeared in the last few years is that of the discovery of platinum in the copper ores of the Rambler mine, already referred to elsewhere in this section. The ore occurs in metamorphic rocks, and exhibits from the surface downward, the iron cap, oxidized ores, covellite and finally chalcopyrite. The platinum is especially rich in the covellite. The assays show quantities from 0·06 to 1·4 oz. per ton. A sample apparently of wall-rock which I have examined microscopically and which has yielded identifiable amounts of platinum, proves to be a baked slate or hornfels, and doubtless came from the contact of an intrusive rock on slates or shales. The rock contains much pyrites. By panning down the covellite, Professors Wells and Penfield have detected crystals of sperrylite.[10]

These discoveries make it extremely desirable to be on the watch for platinum and its associated metals in copper ores. Comparatively minute quantities may have been overlooked in the past and yet may be profitably saved in modern methods of electrolytic refining, especially while platinum rules at its present quotations. Its occurrence is, however, exceptional, and tests of electrolytic residues in some of our largest copper refineries have failed to show it.

It is likewise important to look for it in deposits of chromite since the latter is its commonest associate. But it is important to appreciate that if platinum should be found not associated with a smelting ore of copper or lead, it will be necessary to recover it by some smelting process or by some method of magnetic extraction, or by some other method which does not involve amalgamation.

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[6] Vanquelin, *Annales de Chemie*, LX., 317, 1806.
[7] E. Gueymard, *Comptes Rendus*, XXIX., 814.
[8] *American Journal of Science*, January, 1869, pp. 67–71.
[9] *Ibid.*, May, 1899, p. 372.
[10] *Ibid.*, February, 1902, p. 95.

POTASSIUM SALTS.

THE world's supply of potassium salts, with the exception of saltpeter, continues to be derived from Germany, where the production is controlled by the Kali-Syndicate which was organized by all the active mines for the protection of common interests and especially to avoid overproduction. The agreement first entered into in 1879 has been renewed and revised from time to time. The last renewal dates from June 22, 1898, was amended on June 29 of that year, and is to run until December 21, 1901. According to this agreement the marketable products are divided into three classes: (1) Crude salt, that is, potassium and magnesium products direct from the mines, not including boracite; (2) manufactured products, so far as they are prepared in the chemical works connected with the mines; (3) mixed salts, mixtures of crude and prepared salts, for fertilizers.

It is understood that early in 1902 an agreement was made by the Kali-Syndicate to supply the Virginia-Carolina Chemical Co. (and probably the American Agricultural Chemical Co. as well) with potassium salts at more favorable terms than those prevailing in recent years. This community of interests resulted from the purchase or option of independent potassium salt properties in Germany by the American companies. The importance of the consumption of potassium salts in the United States is reflected by the large quantity imported annually from Germany. In 1901 the aggregate imports of potassium salts exceeded 100,000 metric tons.

The Kali-Syndicate by its agreement determines not only the sale and the prices of the different products but it has also decided the exact amount which each mine may contribute to the total output. In this connection the products of the mines are divided into four classes, according to their percentage of potassium, as follows: (1) Products with more than 48% K_2O, an equivalent of 76·1% KCl or 88·9% K_2SO_4. (2) Products with not more than 48% K_2O nor less than 18%, equivalents of 76·1 to 28·5% KCl or 88·9 to 33·3% K_2SO_4. (3) Crude salts (not carnallite) with 12·4 to 18% K_2O, equivalents of 19·7 to 28·5% KCl or 23·0 to 33·3% K_2SO_4. (4) Carnallite salts with less than 12·4% K_2O. The percentage of potash is made the basis for determining the amount of salts of each kind which any manufacturer may offer for sale, but no restrictions are put on the output of the crude material so long as it does not come into the

market. Class 1 includes mostly refined products; class 2, both refined and crude; classes 3 and 4, crude only. A method for separating classes 3 and 4 was adopted, and will prevent carnallite salts which contain a high percentage of potash being sold under class 3. It is based on the relative solubilities of carnallite and kainite in 96% alcohol, the magnesium chloride in the kainite being insoluble, while it is soluble when occurring in carnallite. Salts which contain more than 6% soluble chlorine are put in class 4.

The quota assigned to each member of the Syndicate for the year 1900 is shown in the following table, which also gives their relative importance. The figures in each column represent the contribution of each mining company per 1,000 metric tons of total output for 1900. Statistics for 1901 are not available at time of publication.

Name of Mining Companies.	Class I.	Class II.	Class III.	Class IV.
Der koeniglich preussicher Bergfiscus	190	180	180	142
Der herzoglich anhaltische Landesfiscus	118	118	120	110
Westeregeln	100	100	102	100
Neu-Stassfurt	100	100	102	100
Aschersleben	100	100	102	100
Ludwig II	72	72	26	80
Hercynia	98	98	101	100
Deutsche Solvay-Werke	100	100	102	100
Thiederhall	46	46	*Nil.*	48
Wilhelmshall	61	61	85	70
Glueckauf	40	40	70	*Nil.*
Hedwigsburg	40	40	60	50
Total	1,000	1,000	1,000	1,000

The works belonging to the Syndicate are supplied with 513 boilers representing 53,250 H.P. and 738 engines of 47,420 H.P. The personnel consists of 818 officers and 15,570 laborers.

It is believed that deposits of potassium salts exist in certain localities, and a company has been prospecting for potassium salts in the United States for several years, but so far without success.

Imports.—The imports and exports of potassium products of the United States are given in the tables at the end of this volume.

The statistics of the Stassfurt salt industry for the past five years are given in the following tables, which were kindly furnished by the Verkaufssyndikat der Kaliwerke, Leopoldshall-Stassfurt, commonly referred to in the trade as the "Kali-Syndicate." Statistics from the beginning of the industry in 1857 to 1895, inclusive, are given in detail in THE MINERAL INDUSTRY, Vol. VIII., pp. 480 and 481.

KALI-SYNDICATE OUTPUT OF CRUDE SALTS OF ALL KINDS. (IN METRIC TONS.)

Year.	Rock Salt. NaCl.	Carnallite. $KCl, MgCl_2+6H_2O$.	Kieserite. $MgSO_4+H_2O$	Sylvinite. KCl.	(a) Hartsalz, Schoenite and Kainite.	Boracite. $Mg_7B_{16}O_{30}Cl_2$.	Total.
1897...	288,036	851,272	2,619	84,105	1,012,186	184	2,238,402
1898...	291,591	990,998	2,444	94,270	1,120,616	262	2,500,171
1899...	310,378	1,317,948	2,066	100,653	1,063,195	155	2,794,395
1900...	(b)	1,697,803	2,047	147,791	1,189,394	223	3,037,258
1901...	(b)	1,860,189	2,335	190,034	1,432,136	(c)	3,484,694

(a) Hartsalz, NaCl, KCl, $MgSO_4+H_2O$; Schoenite, $K_2SO_4, MgSO_4+6H_2O$. Kainite, $KCl, MgSO_4+3H_2O$.
(b) No longer compiled. (c) Not stated.

UTILIZATION OF THE CRUDE POTASSIUM SALTS. (IN METRIC TONS.)

Year.	Carnallite and Rock Kieserite.				Kainite and Sylvinite (a) (including Hartsalz and Schoenite).			
	For Agricultural Purposes.		For Manufacturing Concentrated Salts	Total.	For Agricultural Purposes.		For Manufacturing Concentrated Salts	Total.
	Germany.	Elsewhere.			Germany.	Elsewhere.		
1897.....	58,544	5,157	790,190	853,891	668,340	295,765	132,185	1,096,290
1898.....	60,793	7,189	925,461	993,443	722,115	334,111	158,660	1,214,886
1899.....	58,677	4,611	1,256,730	1,320,018	717,637	314,869	131,342	1,163,848
1900.....	55,489	2,869	1,641,493	1,699,851	724,624	375,007	237,554	1,337,185
1901.....	77,802	7,382	1,777,280	1,862,524	859,115	494,220	268,835	1,622,170

(a) Quantities of sylvinite containing more than 18% potash.

PRODUCTION OF CONCENTRATED SALTS. (IN METRIC TONS.)

Year.	Potassium Chloride. 80%	Potassium Sulphate. 90%	Sulphate. Potassium—Magnesium		Kieserite; Ground and Calcined.	Kieserite in Blocks.	Potash Manure Salt. (a)
			Crystalliz'd 40%	Calcined. 48%			
1897.....	156,863	15,403	922	7,415	214	25,669	23,042
1898.....	174,380	17,781	914	10,535	728	19,934	24,284
1899.....	180,672	24,656	579	8,459	260	28,216	70,916
1900.....	206,471	34,255	932	12,150	358	28,508	129,863
1901.....	197,474	28,159	7,513	11,750	361	26,727	140,688

(a) Quantities containing 38% potash.

MARKETS IN 1901.

United States.—The prices established by the Kali-Syndicate for the year 1902, for New York, Boston, Philadelphia and Baltimore per 100 lb. are as follows: Muriate of potash, 80 to 85%, basis 80%, $1·80; muriate of potash, minimum, 95%, basis 80%, $1·83; sulphate of potash, 90%, basis 90%, $2·08; sulphate of potash, minimum 96%, basis 90%, $2·11; double manure salt, 48 to 53%, basis 48%, $1·09; manure salt, minimum, 20% potash, 62c. For Norfolk, Va., Charleston, Savannah, Wilmington, N. C., and New Orleans, La., add 3·5c. to the New York prices for muriate of potash salts, 3c. for sulphate of potash salts and 2·5c. for double manure salt. For bulk salts on basis of foreign analysis, kainite testing 12·4% potash is quoted for New York at $8·80 per ton of 2,240 lb., invoice weight at shipping port, or $9·05 actual weight at receiving port; sylvinite, 38c. per unit of sulphate of potash, invoice weight at shipping port, or 39c. per unit, actual weight at receiving port. Kainite prices for Norfolk, Charleston and other Southern ports are 50c. higher, while sylvinite is 2c. per unit higher for Norfolk, Charleston and other Southern ports. These prices are for not less than 500 tons of bulk salts or 50 tons of concentrated salts, and are based on river shipment from the mines to the seaport. For rail shipments an additional amount of 40 pfennigs per 100 kg. or 5c. per 100 lb. is required.

Germany.—The following prices for the different products in 1900 have been

% KCl.	Marks for 80% KCl. (a)	% KCl.	Marks for 80% KCl. (a)	% KCl.	Marks for 80% KCl. (a)
80–85	14·25	90–95	14·55	97– 98	14·95
85–88	14·35	95–96	14·75	98–100	15·15
88–90	14·45	96–97	14·85	(b) 98–100	15·25

(a) One mark=23·8c. The prices are all based on 80% KCl; the excess is charged for at different rates according to the exact analysis of the material. Thus, 84% KCl would cost 14·25 marks plus 0·7125 marks (4% KCl at basis of 14·25 marks for 80%), or 14·9625 marks. (b) With not more than 0·5% NaCl.

furnished by Dr. F. Klockmann. (Prices for 1901 not at hand.) They include package and are f. o. b. Stassfurt:—

A.—Potassium Chloride. (Prices per 100 kg. in amounts not less than 50 metric tons.)

B.—Potassium sulphate (high grade, in any amount).—For minimum of 90% K_2SO_4 and maximum of 2·5% Cl, 16·45 marks per 100 kg. 90%; for minimum of 96% K_2SO_4 and maximum 1% Cl, 16·85 marks per 100 kg. 90%.

C.—Double sulphate of potassium and magnesium (in any amount).—Calcined, containing a minimum of 48% K_2SO_4 and a maximum of 2·5 Cl, 8 marks per 100 kg. 48%; crystallized, containing a minimum of 40% K_2SO_4 and a maximum of 1% Cl, 6·40 marks per 100 kg. 40%.

D.—Potash fertilizer (exclusive of package in carload lots).—For minimum of 20% pure potash, 3·10 marks per 100 kg.; for minimum of 30% pure potash, 4·75 marks per 100 kg.; for minimum of 40% pure potash, 6·40 marks per 100 kg.

E.—Kieserite, calcined and ground (in any amount).—For a minimum of 70% $MgSO_4$, 2·60 marks per 100 kg., and no additional change for an excess of that percentage.

The rapid strides made by the potash industry are evident in the statistics of production, according to which the total output of salts in 1861 was 2,293 metric tone, but in 1900 amounted to over 2,000,000 tons.

Progress in the Chlorate and Hypochlorite Industries in 1901.

By J. B. C. Kershaw.

Chlorates.—Little change has occurred during 1901 in the electrolytic chlorate industry. The number of works remains stationary at ten, and the power available for the manufacture in these ten factories lies between 30,000 and 40,000 H.P. Further details of the factories for chlorate production are given in Table I.

TABLE I.—ELECTROLYTIC CHLORATE WORKS IN OPERATION IN EUROPE AND AMERICA DURING 1901.

No.	Name of Company.	Locality of Works.	Horse Power.		Source of Power.	Process Used.
			Available	Utilized		
1	Messrs. Corbin et Cie	Chedde	12,000	9,000	Water..	Corbin open cell.
2	Société d'Electrochimie	St. Michel	4,000	(?)	Water..	Gall & Montlaur cl. cell.
3	Société d'Electrochimie	Vallorbe	3,000	(?)	Water..	Gall & Montlaur cl. cell.
4	Superfosfat Fabriks Altiebol A. G.	Mansboe	4,000	(?)	Water..	Carlsen cell.
5	Superfosfat Fabriks Altiebol A. G.	Alby	(?)	(?)	Water.,	Carlsen cell.
6	Consortium f. Elektrochemische Industrie	Ginliog	4,500	(?)	Water..	Kellner cell.
7	Gesellschaft f. Elektrochemische Industrie	Turgi	800	600	Water..	(?)
8	The North American Chemical Co.	Bay City	2,000 ?	2,000 ?	Steam..	Hurter cell.
9	The National Electrolytic Co.	Niagara Falls	.....	2,000	Water..	Gibbs open cell.
10	The Chemical Construction Co.	Niagara Falls	.....	500	Water..	Blumenberg closed cell.

No very reliable figures for the total output of chlorates in 1901 can be obtained, and estimates based on the power available are misleading. Most of the companies engaged in the manufacture of electrolytic chlorates produce other products, and since the fall in the price of potassium chlorate below 3·5d. per lb. the tendency has been to devote an increasing proportion of the power to the production of perchlorates and persulphates.

From figures for individual works, it is calculated, that about 10,000 tons

potassium and sodium chlorates were produced by electrolysis in 1901, and that the output of the electrolytic works is slowly increasing, at the cost of the works still operating the chemical process. As an example of the relative positions of the two processes in France, the following figures published by Guillet for the year 1899 are instructive: Electrolytic works (2), 3,000 tons; chemical works (2), 850 tons; total, 3,850 tons.

Two companies have increased their production during 1901, the National Electrolytic Co. at Niagara Falls, N. Y., and Messrs. Corbin et Cie. at Chedde, France. The former company is now using 2,000 H.P. in the manufacture, in an improved form of the original Franchot & Gibbs cell. This cell is constructed on the filter press principle, without a diaphragm, and has anodes of thin platinum foil, and cathodes of copper wire. An illustrated description of the cell and process has appeared during 1901.[1] Messrs. Corbin et Cie. at Chedde have increased their production, chiefly by improving the efficiency of the cell process. The details of the improvements are not available for publication, but it is probable that they are based upon the use of potassium or sodium chromate in the electrolyte. A small percentage of this compound has a remarkable and unexplained effect in raising the yield of chlorate. At Chedde the ampere hour efficiency has been raised from 42 to 85% and it is expected shortly to attain a current efficiency of 90% in the cell process. In this way, using the same plant and power, the production has been increased from 2,200 tons in 1899, to 4,500 tons, and the works at Chedde now produce more chlorate than any other factory in the world. A market for this chlorate is found in Germany, Italy, America, and Japan, and large quantities are used in the manufacture of a new explosive called "Cheddite." The chemists of the Société d'Electrochimie, at St. Michel and Vallorbes, where the Gall & Montlaur process is worked, are also reported to have considerably improved the efficiency of the process, but details are lacking.

As regards the theory of electrolytic chlorate production, Brochet has published the results of laboratory investigations,[2] which prove that, in all cases, hypochlorite is an intermediate product. The conversion of this hypochlorite into chlorate is the result of a secondary chemical reaction in the cell, and it is in this conversion that the presence of chromate plays a remarkable rôle. In Brochet's own experiments, the reduction at the cathode was diminished sevenfold, when chromate was added to the electrolyte.

Moody & Tucker also have recently investigated the action of chromates, when used with an electrolyte of calcium chloride, and they find that under stated conditions of work, an efficiency of between 76 and 86 per cent. can be attained, for long periods of electrolytic action.[3] In these experiments, the platinum electrodes were horizontal and spaced 10 cm. apart, a current density of 8 amperes per sq. dc. of anode surface was used, and the temperature of the electrolyte was maintained at 80°C. It is hoped that this investigation may lead to the utilization of the waste calcium chloride liquors of the ammonia-soda works.

Hypochlorites.—Although the use of hypochlorite solutions produced by

[1] *The Electrician*, Dec. 18, 1901.
[2] *Elektrochemische Zeitschrift*, February, 1901.
[3] *Journal of the Society of Chemical Industry*, November, 1900.

electrolysis for bleaching purposes is believed to be extending, little detailed information concerning the progress made in 1901 is available for publication.

The experimental trials which were started at Bradford, England, in 1899, have been suspended, as the results obtained were unsatisfactory. Entirely satisfactory working has followed the introduction of the process elsewhere, and one can only assume that the apparatus used in these experiments at Bradford was defective, or that the men in charge of it were responsible for its failure. Further trials with the electrolytic method of producing bleaching solutions, are however likely to be made in the United Kingdom, as the Electric Bleaching Co. with a capital of £15,000 has been registered during 1901, to purchase and work two patents granted to A. Vogelsang, relating to electrolytic hypochlorite cells. The Vogelsang cell as stated in my last report in THE MINERAL INDUSTRY, Vol. IX., is already operating at several bleaching works in Saxony.

With regard to France, it is stated that the obstacle to the extended use of the electrolytic method is the large supply of bleaching powder which can be obtained at unusually low prices by the bleach works. Both France and Germany contribute to this overproduction of bleaching powder, the output of each having been greatly increased in recent years by the erection and operation of so many electrolytic alkali works.

The largest installation of electrolytic hypochlorite cells in France of which definite information has been given, is at the cellulose factory of Corbin et Cie. at Lancey. The process and cell used here is patented in the name of Paul Corbin, and 700 H.P. is said to be utilized in the production of 1,000 tons bleached cellulose per annum. The cell is characterized by a large number of secondary platinum electrodes held in ebonite frames, with an external structure of cement. The Hermite cell is reported to be in use at a paper works at Essones, and at one or two textile bleaching works.

In Germany, a very large number of the textile bleaching factories in Saxony and Bavaria use the new method of preparing the bleaching solutions, and cells patented under the names of Kellner, Vogelsang, and Haas & Oettel, are found in these works. Little new information concerning the progress made in these districts has been published during 1901. Oettel has however given figures showing the yields obtained with the Haas & Oettel apparatus and has stated that 100 of these are now in use in various works in Saxony. Replying to criticisms by Engelhardt who had claimed a higher efficiency for the Kellner type of cell,[4] Oettel has shown that at high concentration of the electrolyte, the Haas & Oettel cell is the cheaper to work. For weak solutions the Kellner is the more economical. As regards first cost, the Haas and Oettel apparatus to yield 11·2 kg. active chlorine in 9 hours costs 2,500 m. ($625), while the Kellner apparatus to yield 36·7 kg. chlorine in 9 hours costs 13,000 m. ($3,250). This difference in cost is due to the fact that in the Kellner apparatus, platinum is used as electrode material; while in the Haas & Oettel cell, specially prepared carbon is employed. When worked out as comparative cost per kilogram of active chlorine, the capital outlay in the latter case must be multiplied by 3·3, and the saving is less striking than appears at first sight.

[4] *Zeitschrift fuer Elektrochemie*, Jan. 31, 1901.

The depreciation with the Haas & Oettel type of cell is estimated at 10%. The carbon electrodes are said to last half a year with proper use. The latest form of Haas & Oettel cell makes use of the pressure of the liberated hydrogen to circulate the electrolyte. In the Kellner apparatus this work is performed by a small pump.

The only note available relative to the use of electrolytic bleaching methods in Austria or Russia, is that the Kellner cell is employed at wood-pulp factories at Gratwein, and at Hallein, in Austria. At the latter works, 200 H.P. is believed to be used, to prepare the bleaching solution, and 15,000 kg. of bleached pulp are produced per day. The brine after electrolysis is reported to contain 1·2% active chlorine. This factory is owned by the Kellner-Partington Paper Pulp Co., which also controls a similar plant at Sarpsfos in Norway. Very few facts have been published concerning the last-named plant, but it is stated that an 800-H.P. Thury dynamo is installed, and that a 5,000-ampere current is generated at 120 volts' pressure.

At Stjernfors, the Hermite cell is reported to be still in use, in a wood-pulp mill producing 1,750 kg. bleached pulp per day; and at Billingsfors in Sweden, a Schuckert installation is in operation, 390 H.P. being utilized, to produce 14 tons bleached cellulose per day. The electrolyzed solution contains 1·4% active chlorine and the cost is said to amount to 182 kr.[5] ($48.77) for 820 kg. active chlorine. This total is made up of the following items: Power, 52 kr.; salt, 107 kr.; wages, 7 kr.; depreciation and repairs, 16 kr. This plant started work in July, 1900.[6]

THE MANUFACTURE OF POTASSIUM CYANIDE.

BY SAMUEL AUCHMUTY TUCKER.

THE growing demand for cyanide has resulted in many new processes being devised for its manufacture, some of which perhaps show more ingenuity than practicability; however, in time it would appear that most of the cyanide will be manufactured by processes other than the older methods of fusion with potash or the working up of by-products from the manufacture of gas.

The Earliest Synthetical Method.—In the earliest process for making cyanides —which is still used to a limited extent—potassium carbonate is fused with a mixture of iron borings and nitrogenous organic matter such as hair, horn, dried blood, leather cuttings, and the like, in the proportion of 1·25 parts of the mixture for 1 part of the potash, the iron borings being in the proportion of 6 to 8% of the organic matter.

Iron pans set in a reverberatory furnace are used, the temperature being kept just hot enough to liquefy the potash but not so high that the cyanogen compounds are volatilized. As soon as quiet fusion is maintained the mass which consists of potassium cyanide, carbonate, and sulphide, together with iron sulphide, is broken into lumps and digested in hot water for several hours. During this period cyanide is converted to ferrocyanide by the reaction:—

$$6KCN+FeS=K_2S+K_4Fe(CN)_6.$$

[5] 1 krone equals 26·8c. United States currency.

[6] *Zeitschrift fuer Elektrochemie*, Sept. 6, 1901.

Liebig's explanation of the process was that cyanogen is formed from the C and N of the organic matter, the potash being reduced to metallic potassium, which unites with cyanogen to form KCN, and the sulphur is taken up by the iron. On lixiviation the above reaction takes place with the formation of the ferrocyanide. The chief objections to the process are loss of potash and more particularly of nitrogen, and the product is impure.

Conversion of Ferrocyanide to the Cyanide of Potassium.—This result is brought about by fusion of the ferrocyanide in a red-hot iron crucible with anhydrous potassium carbonate in the proportion of 8 parts of the former to 3 of the latter. The reaction is: $K_4Fe(CN)_6+K_2CO_3=Fe+CO_2+KCNO+5KCN$. Fusion of the ferrocyanide alone yields: $K_4Fe(CN)_6=4KCN+FeC_2+N_2$ The iron carbide formed sinks to the bottom, but not nearly so perfectly as the metallic iron produced in the first case, and consequently results in a more impure product; besides there is a loss of available carbon and nitrogen. In any case the cyanide is contaminated with cyanate and very largely so unless the air is carefully excluded.

Ferrocyanide may also be converted to cyanide in a state of great purity by means of metallic sodium which is now prepared very cheaply by the Castner and other processes. The ferrocyanide in fusion is subjected to the action of melted sodium, which results in the formation of a mixture of potassium and sodium cyanides if potassium ferrocyanide is employed, or in pure sodium cyanide if the raw material is sodium ferrocyanide. This admixture produces a cyanide which, tested by ordinary methods for cyanide of potassium, would assay over 100%, so enough potassium carbonate is added in the commercial product to reduce the assay test to from 98 to 99% pure potassium cyanide. A large part of the potassium cyanide in use is made by this or similar methods. The reaction takes place as follows: $K_4Fe(CN)_6+2Na=4KCN+2NaCN+2Fe$.

The Manufacture of Cyanide from Ammonia.—In experiments made to form cyanides by passing atmospheric nitrogen over red-hot carbon together with potash, it was soon found that if ammonia was used instead of nitrogen the yield was increased. Several patents have been taken out using this source of nitrogen, and Young and Macfarlain[1] found that there was a great advantage in using a combination of carbonic oxide with the ammonia, for which they took out a patent in 1892. They claim to have produced a 70% cyanide working on these lines, but J. T. Conroy,[2] who repeated their experiments, failed to get more than a 30% cyanide, and showed that using ammonia alone resulted in but 4% of it being converted to cyanide. W. Siepermann and others suggested the use of barium carbonate to be mixed with the potash which renders the charge more infusible.

A plant is now in course of erection at Manchester, England, in which cyanide is to be manufactured by the Grossman process,[3] which depends upon the action of ammonia but has several new features. Ammonia gas is passed over a heated mixture of potassium sulphide, carbon, and sulphur in a suitable retort. Potassium cyanide is the chief product formed, together with a small quantity

[1] English Patent No. 8,092, 1892. [2] *Journal of the Society of Chemical Industry*, 1896.
[3] United States Patent No. 671,479.

of sulphocyanide, which can be neglected. The retorts are so arranged that the gas may be passed from one to the other, and the mixture is chosen to avoid caking at the temperature employed, *i.e.*, 700 to 800°C. When the reaction is completed the mass is withdrawn and lixiviated, by which means the potassium cyanide is obtained, or by the addition of a suitable iron salt ferrocyanide may be prepared. The process seems to promise well, and its success will probably depend upon how much of the ammonia can be converted to cyanide. One drawback to the use of ammonia is found in the action which always takes place between that gas and metals at high temperatures. It has recently been shown[4] that there is no metal which will withstand its action, and consequently the deterioration of apparatus is likely to be a large item.

Castner[5] took out a patent in 1894 for the manufacture of cyanide by the use of metallic sodium upon hot carbon together with nitrogen, but ammonia was soon substituted for the nitrogen. Vertical iron retorts are used, melted sodium being passed downward over the heated carbon, while anhydrous ammonia is admitted below. The temperature is low (300 to 400°C.) and the reaction taking place is in two stages, as follows: $NH_3+Na=NaNH_2+$. Then sodium amide reacts with the carbon producing: $NaNH_2+C=NaCN+H_2$.

Cyanide from Sulphocyanides.—Sulphocyanides may be prepared according to the process of Gelis, which has been modified by Tscherniak and Gunzburg[6] which consists in heating carbon-disulphide and ammonia under pressure. The temperature is 125°C., and the mixture is agitated in an autoclave. The first reaction to take place is the formation of ammonium-di-thiocarbamate:—

$$CS_2+2NH_3=NH_4S_2CNH_2,$$

which changes to sulphocyanide as follows: $NH_4S_2CNH_2=NH_4SCN_2+H_2S$. The hydrogen sulphide exerts an enormous pressure which requires the use of expensive apparatus and this was obviated by Hood and Salamon[7] in 1891, who improved the process by using Weldon manganese residues to absorb the gas, but a still greater advantage was found in the use of slaked lime, for which Hurter[8] and others took out a patent in 1893. The reaction may be expressed as follows:

$$2CS_2+2NH_3+MnO_2+CaO=Ca(SCN)_2+MnS+S+3H_2O.$$

Conroy obtained a quantitative production working on these lines.

Conversion of Sulphocyanide to Potassium Cyanide.—Playfair[9] investigated this question, making numerous experiments with different metals having an affinity for sulphur, and came to the conclusion that zinc was the most efficient. The sulphocyanide is added to the fused zinc and the two thoroughly incorporated, by which means the sulphur is removed as zinc sulphide which may be converted to metallic zinc again or oxidized to sulphate. These results have since been confirmed by Conroy.[10] Another method for the removal of the sulphur

[4] "The Action of Ammonium upon Metals at High Temperatures," G. T. Beilby and G. G. Henderson, *Journal of the London Chemical Society*, November, 1901, 1245.

[5] English Patents Nos. 12,218 and 21,732 of 1894.

[6] *Dingler's Polytechnic Journal*, 245, 214.

[7] English Patent No. 5,854 of 1891.

[8] English Patent No. 21,451 of 1893.

[9] *Journal of the Society of Chemical Industry*, 1892, 4.

[10] *Journal of the Society of Chemical Industry*, 1898, 98.

is that of Raschen,[11] which depends upon the oxidation of the sulphur. The process is said to be in use in England at the present time. Stated briefly, nitric acid acts upon sodium sulphocyanide oxidizing the sulphur to sulphate, being itself reduced to nitrogen monoxide which is subsequently oxidized again to nitric acid by atmospheric oxygen. The reactions taking place are in two separate stages:—

$$NaSCN+2HNO_3=HCN+NaHSO_4+2NO \text{ and } 2NO+3O+H_2O=2HNO_3.$$

Fawsitt proposed oxidizing the sulphur in solution by means of some suitable oxidizing agent such as permanganate.

Production of Cyanide from Gas Works.—It has long been known that in the distillation of coal that some of the nitrogen present is converted to cyanogen compounds. In 1845 Bunsen and Playfair investigated the formation of cyanide in the blast furnace, and proposed a method for its manufacture. There is no doubt that considerable cyanide is formed in both the blast furnace and in coking, but up to the present time no economical method has been devised for its extraction.

In the destructive distillation of coal for illuminating gas, however, much work has been done dealing with cyanide manufacture. Just how cyanide is found in coal gas is not quite clear, but the following points are now understood and have been pointed out by H. Poole:[12] (1) Cyanogen is known to be in the crude gas as hydrocyanic acid, ammonium cyanide, and sulphocyanide, but not as ferrocyanide. (2) Prussian blue is found in the purifier under ordinary circumstances only in small quantities. (3) Sulphocyanides may form in the purifier when no sulphocyanide is present in the gas, and ammonia favors their formation.

Both ammonium sulphocyanide and potassium ferrocyanide are now prepared in considerable quantities from the spent iron oxide in the purification of illuminating gas. The spent oxide is first treated with water at 60°C., until the liquor has a density of 1·07. The solution is then concentrated to 1·2 sp. gr., and allowed to crystallize. In this way crude ammonium sulphocyanide is obtained which is purified by recrystallization, and may be converted to cyanide by the methods already pointed out.

J. Bueb[13] took out a patent in 1898 for improvements in the extraction of cyanides from coal gas, and at present the process appears to be a promising one. It not only aims at the extraction of the cyanide but also lends itself to the purification of the gas, for hydrocyanic acid and cyanogen compounds generally are known to corrode the meters or other gas apparatus.

The crude gas is passed into a special washer after it has traversed an atmospheric condenser and tar extractor, in which is run a solution of ferrous sulphate of 17 to 19°B., arranged to traverse the washer in an opposite direction to that of the gas. The reactions taking place are the following:—

$$FeSO_4+H_2S+2NH_3=FeS+(NH_4)_2SO_4.$$
$$2FeS+6NH_4CN=(NH_4)_2Fe(CN)_6+2(NH_4)_2S.$$

[11] English Patent No. 21,678 of 1895.
[12] *Journal of Gas and Lighting*, 70 [1904], 1234-1236.
[13] English Patent No. 9,075 of 1898.

The product, which is in the form of a thin mud, is then pumped out and contains 6 to 8% ammonia and an equivalent of 20% ferrocyanide of potassium. This is distilled for the ammonia and the residue worked up for Prussian blue and yellow prussiate. The quantity of cyanogen obtained of course varies with the variety of coal employed, but according to Bueb, 7·4 oz. are obtained from 1,000 ft. of gas furnished from English coal and somewhat less with other European coals.

Cyanides from Atmospheric Nitrogen.—The formation of cyanogen by combination of heated carbon and the nitrogen of the air is impracticable, not to say impossible, under ordinary conditions. It can, however, be accomplished by the addition of a suitable alkaline earth base, and this was suggested by J. Young,[14] but his process calls for a comparatively low temperature; and what is actually required is the formation of a suitable alkaline earth carbide which requires a high temperature, and then the subsequent transformation of this carbide to cyanide by means of atmospheric nitrogen for which a lower temperature is necessary.

This idea has been successfully carried out by the Bradley-Jacobs patent.[15] The process consists in coking a mixture of barium carbonate and small coal in a retort, which results in a very porous material. This porous mixture is then subjected to a high temperature in a rotary electric furnace, resulting in the formation of a porous carbide of barium. The next step is the addition of nitrogen gas, derived from producer gas or directly from the atmosphere, at a lower temperature, by which means barium cyanide is formed. The barium cyanide is then easily converted to any particular cyanide desired, the process being carried out continuously. Experimentally, the method has succeeded, and it is shortly to be put in operation at Niagara Falls.

Processes of a similar nature have been brought out abroad by Dr. A. Frank in 1895, and by Dzink in 1899, but the first is not a continuous process, and the second does not take advantage of the lower temperature necessary for the formation of cyanide from the carbide. The reactions taking place in the Bradley-Jacobs process are the following:—

$$2BaCO_3+7C=2BaC_2+3CO_2 \text{ and } BaC_2+N_2=Ba(CN)_2.$$

[14] English Patent No. 24,856 of 1898.

[15] United States Patents, Nos, 657,937 and 658,698, September, 1900.

QUICKSILVER.

THE production of quicksilver in the United States during 1901 amounted to 29,727 flasks, against 27,855 flasks in 1900, due to the development of the Rhodin and other electrolytic processes for the manufacture of soda and chlorine which have consumed an increased amount.

PRODUCTION AND EXPORTS OF QUICKSILVER IN THE UNITED STATES.

Year.	Production.			Exports.			Year.	Production.			Exports.		
	Flasks.	Met. Tons.	Value.	Flasks.	Met. Tons.	Value.		Flasks.	Met. Tons.	Value.	Flasks.	Met. Tons.	Value.
1896..	29,863	1,036	$1,104,997	19,944	692	$618,437	1899....	28,879	993	$1,155,160	16,518	573	$609,586
1897..	26,079	905	910,418	13,173	475	304,549	1900....	27,855	967	1,288,851	10,172	353	425,812
1898..	30,493	1,058	1,109,945	12,830	445	440,587	1901....	a29,727	1,031	1,382,305	11,219	389	475,609

(a) The total production is divided as follows: California, 26,720 flasks; Texas, 2,932 flasks; Oregon, 75 flasks.

The imports of quicksilver during the past five years were as follows: 1896, $2,037; 1897, 45,539 lb. ($20,147); 1898, 81 lb. ($51); 1899, 131 lb. ($83); 1900, 2,616 lb. ($1,051); 1901, 1,441 lb. ($789).

California.—(By B. M. Newcomb.)—Notwithstanding the increased output of more than 2,000 flasks of quicksilver during 1901, the stock in sight unsold, including New York, January 1, 1902, was but 2,230 flasks. In California two new mines have been added to the list of producers during 1901: the Karl mine, which produced 600 flasks during the last three months of the year, and the Libertad, both in San Luis Obispo County. The largest producers were the New Idria, of San Benito County; Napa Consolidated, of Napa County; and New Almaden, of Santa Clara County, the production of these being about equal. Several of the older producing mines fell off materially in production, which shortage was offset by several small prospects outfitted with retorts.

The cost of producing quicksilver from the average California mine fully equipped with modern plant and well developed, will exceed $35 per flask. Add to this cost interest on plant and cost of development work, and the outlook for opening new property is not encouraging. Many mines of the coast are producing at a cost of over $40 per flask. This heavy cost is largely by reason of a large decrease in the grade of ore encountered in the older properties and by small veins in the newer properties opened up, many of these latter being mines that were idle during the low prices of quicksilver. Modern quicksilver furnaces have reduced the cost of reduction as low as 50c. per ton in one or two plants,

but the average price of reduction of the plants of larger equipment is 65c. to 70c. per ton.

The lowest cost of mining the ore that is reported is an average of $1·82 per ton. One important producer reports $2·50 per ton, another $3·50, and others estimate their cost as high as $8·50 to $10 per ton. The cost per lineal foot of development work varies largely also, and is reported from $2·50 per ft. for the lowest to $10·50 among the highest for tunnel work. In shaft work and drifting from same, the expense will run higher. The average yield reported comes under 0·6% Hg, the lowest 0·3% Hg, while two important producers and dividend payers report 0·56% Hg. Under very favorable circumstances with a large body of ore a profit can be made on 0·25% Hg at the present price of quicksilver. This grade, however, requires exceptionally good management combined with favorable facilities. The outlook for an increased production of quicksilver is unfavorable. Many of the older producers are falling off in their output and no new mines of importance are being discovered, newspaper reports notwithstanding. One other of the Texas mines has been equipped with a good furnace and may increase the output for a time, provided the California mines keep up their present rate of production; however, the indication is that the Coast production will fall off as much as Texas will increase.

The total production of quicksilver in California in 1901 amounted to 26,720 flasks, against 25,922 flasks in 1900. The price of quicksilver during 1901 in San Francisco ranged from $46@$48 per flask for domestic and $44@$45 for export. London prices fluctuated somewhat during the year, from £9 2s. 6d. to £8 17s. 6d., the average price per flask being lower than in 1900. The Napa Consolidated Quicksilver Mining Co. produced 4,800 flasks, against 4,550 in 1900. The ore mined and treated was 33,930 tons, from which the average yield was 0·54% Hg. The cost of mining, development work and general expense was $3·94, and the cost of reduction was $0·66 per ton of ore. The amount of tunnels, drifts, and winzes excavated during the year was 9,488 ft. at a cost of $2·43 per ft. The Ætna Consolidated Quicksilver Mining Co. neither mined nor treated any ore during the year, the work being confined to opening old and new bodies of ore in the course of which 4,384 ft. of old tunnels and 83 ft. of old winzes were opened at a cost of $1·05 per ft., besides which 1,995 ft. of new tunnels and drifts were excavated at an average cost per foot of $4·97, to develop a new ore body discovered from shallow surface working. The company recovered from cleaning the old condensers 228 flasks of quicksilver, which realized $10,290. The deficit for the year $18,418, reduced the balance brought forward from the previous year amounting to $79,129 to $60,711. The New Idria Quicksilver Mining Co. mined and treated 31,866 tons of ore for a recovery of 4,800 flasks or an average yield of 0·576% Hg. A new furnace was erected and put into operation during the year. The cost of reduction of the ore was $0·64 per ton. The cost of mining per ton, including development work, was $1·82, and 1,422 ft. of tunnels, raises and drifts were excavated at a cost per ft. of $4. The sales of quicksilver realized $211,484; increase of supplies, $104; interest, $416; total, $212,004. The total expenses were $155,649, leaving a net balance of $56,355. Dividends of $60,000 were paid, leaving a deficit of $3,645, which being

deducted from the reserve of the previous year amounting to $44,574, left a surplus of $40,929 carried forward. The Boston Quicksilver Mining Co. mined and treated 19,045 tons of ore for a yield of 1,545 flasks of quicksilver, which was obtained at a cost for mining, including development work, of $2·58 per ton, while the cost of reduction amounted to $0·61 per ton. The amount of tunnels, drifts and winzes excavated was 2,507 ft. at an average cost of $2·50 per ft. A new furnace was completed and put into service during the year and the old furnace closed down for repairs.

QUICKSILVER PRICES PER FLASK AT SAN FRANCISCO IN 1900 AND 1901.

Month.	Domestic.				Month.	Domestic.			
	1900.		1901.			1900.		1901.	
	Highest.	Lowest.	Highest.	Lowest.		Highest.	Lowest.	Highest.	Lowest.
January.....	$52·00	$51·00	$47·50	$47·00	July	$51·00	$49·50	$48·00	$48·00
February....	51·50	51·50	47·00	47·00	August.....	50·00	48·00	48·00	46·50
March.....	51·50	51·50	47·00	46·50	September..	49·00	48·50	47·50	47·50
April	52·00	51·50	46·50	46·00	October.....	48·50	47·50	47·50	47·50
May	51·50	51·50	47·00	46·50	November ..	48·50	48·00	47·50	46·50
June	51·00	49·50	48·00	47·00	December...	48·00	48·00	47·50	47·50

The price of quicksilver for export during 1900 varied from $47·50 per flask in January to $45 per flask in December. During 1901 it was practically constant at from $44 and $45.

Oregon.—The production of the Blackbutte quicksilver mine in Lane County amounted to 75 flasks during 1901, the small production being due to the necessity of blocking out greater ore reserves, the furnace being closed the greater part of the year for that purpose.

Texas.—The total production of quicksilver during 1901 was 2,932 flasks, against 750 flasks in 1900. The only producers in 1901 were the Marfa & Mariposa Mining Co., and the average price received was $45·17 f. o. b. Marfa. The Lindheim & Dewees furnace was not started until early in 1902, and neither McKinney & Parker nor John Gaughran made any production during 1901, although both produced in 1899 and 1900.

QUICKSILVER PRODUCTION OF THE WORLD. (*a*) (IN METRIC TONS.)

Year.	Austria.	Canada.	Hungary	Italy.	Japan.	Mexico.	Russia.	Spain.	United States.	Total.
1896.....	564	2·0	1·1	186	1·8	218	491	1,524	1,086	4,021
1897.....	532	0·3	0·7	192	2·7	294	616	1,728	965	4,327
1898.....	491	*Nil.*	6·8	173	1·4	353	362	1,691	1,058	4,128
1899.....	536	*Nil.*	27·0	205	*Nil.*	324	360	1,357	993	3,775
1900.....	510	*Nil.*	31·8	260	*c* 2·7	*b* 335	304	1,095	968	3,487
1901.....	512	*Nil.*	*c* 40·0	278	*c* 2·8	*b* 335	368	846	1,081	3,413

(*a*) From official reports of the respective governments and direct reports of the producers to THE MINERAL INDUSTRY. The figures for Austria and Italy for 1898 are due to V. Spirek, that for Russia to the sole producer, and that for Spain to the *Revista Minera*. (*b*) Estimated imports. (*c*) Estimated.

Austria.—Samples of cinnabar ore from the Spizza and Nehaj mines in Dalmatia yielded by assay as follows: Samples Nos. 1, 2 and 3 from Spizza, 1·448%, 4·56%, and 1·49% Hg, respectively. Sample No. 4 from Nehaj yielded 2·599% Hg and 94·4% $BaSO_4$. The total production of quicksilver in Austria for 1901 amounted to 512 metric tons, while Hungary produced about 40 metric tons.

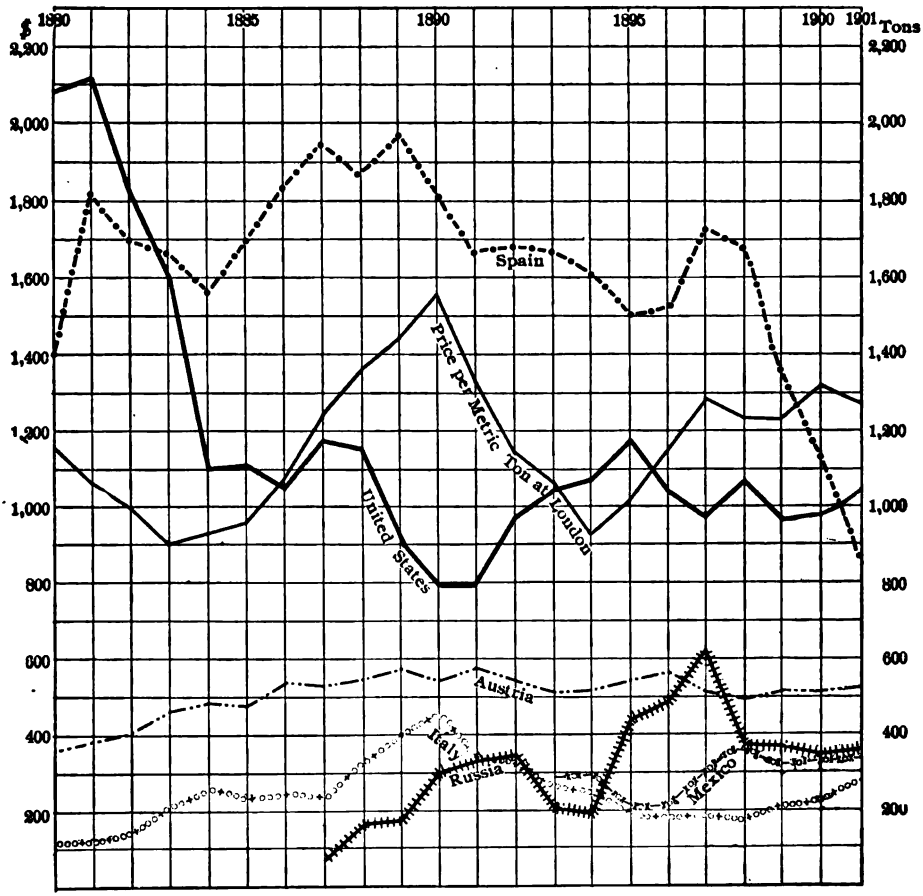
China.—The quicksilver mines in Kwei Chou Province were worked by an

English company during the latter part of 1901, which produced up to June, 1902, about 500 flasks of quicksilver, which was sold in Hong Kong. A large amount of machinery is being transported to the mines, and more extensive work is expected in the near future.

LONDON QUICKSILVER STATISTICS. (*a*)

	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.
	Flasks. (*b*)	Flasks. (*b*)	Flasks. (*b*)	Flasks. (*b*)	Flasks. (*b*)	Flasks. (*b*)	Flasks. *b*)	Flasks. (*b*)
Shipments from Spain to London	42,414	40,409	40,949	46,577	46,367	45,729	10,963	*c* 45,063
Shipments from Italy to London	8,700	5,775	3,800	4,450	5,650	6,206	6,045	*c* 5,257
Total	51,114	46,184	44,799	51,027	52,017	55,935	17,008	50,319
Shipments from London	41,046	37,937	31,273	31,734	31,026	31,903	24,958	*c* 26,830
Maximum price of Spanish	£6 15s.	£7 7s. 6d.	£7 5s.	£7 7s. 6d	£7 15s.	£9 12s. 6d	£9 12s. 6d	£9 2s. 6d
Minimum price of Spanish	5 10s.	6 7s. 6d.	6 8s. 6d	6 12s. 6d	7 0s.	7 15s.	£9 2s. 6d	8 17s. 6d

(*a*) From W. Sargant & Co.'s Annual Metal Circular. (*b*) American, Russian and Italian flask, 76·5 lb. (34·7 kg.); Mexican flask, 75 lb. (34·03 kg.); Spanish flask, 76 lb. (34·5 kg.). (*c*) For the year ending Nov. 30, 1901.



WORLD'S PRODUCTION OF QUICKSILVER IN METRIC TONS

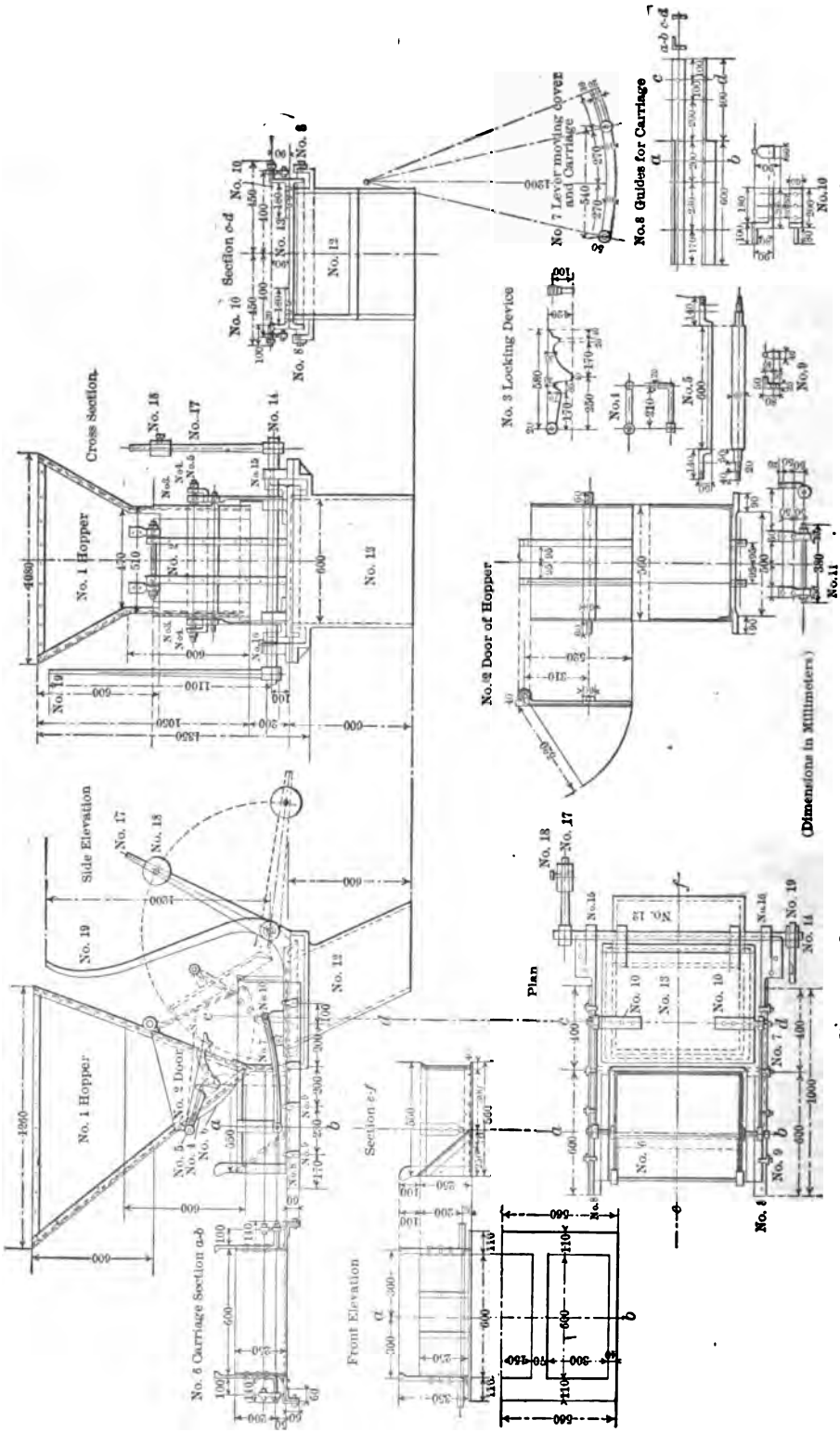
THE CERMAK-SPIREK SHAFT FURNACE FOR QUICKSILVER ORES.

THE Cermak-Spirek furnace (see illustrations, pp. 560 and 561) was built in 1896 as a double-shaft furnace for a daily capacity of from 12 to 15 tons of ore. The shafts rest upon 6 columns (covered with sheet iron to prevent seepage of quicksilver) and measure 1·2 m.×1·2 m.×5·1 m. in height. The contents of the shafts are supported on movable round plates which when moved aside permit the escape of the spent ore. The ore, broken to sizes ranging from 35 mm. to 200 mm., is charged with 2% charcoal in quantities of 500 kg. every two hours. The vaporized quicksilver and the combustion gases are conducted through two pipes to Cermak-Spirek condensers.

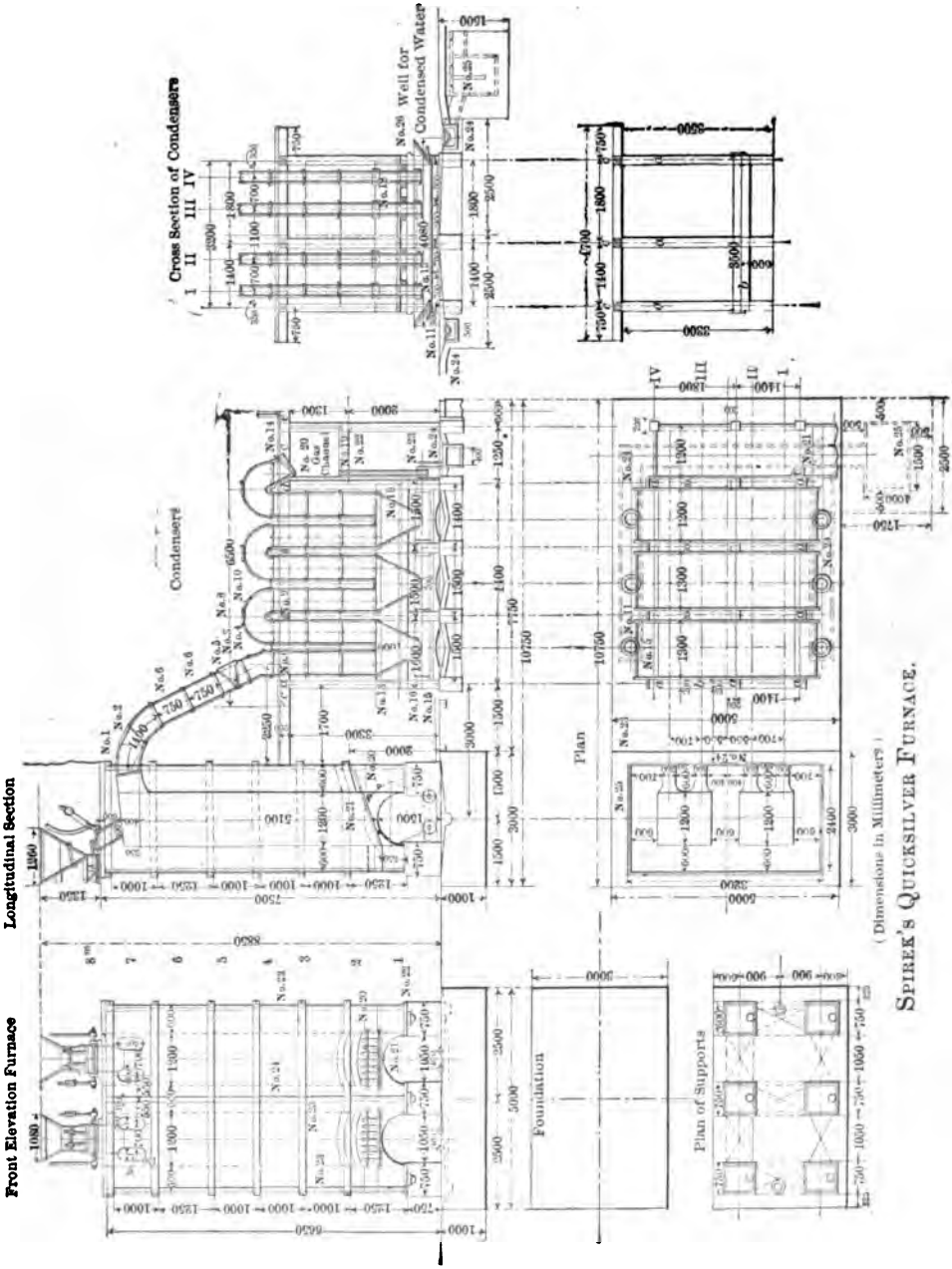
Of great importance is the Cermak charging apparatus, which is intended to prevent the escape of gas during charging. The charger is operated by a lever by an operator protected from the noxious gases. It consists of a spitzkasten with an opening, the charging funnel with water-sealed cover and the carriage (schlitter). At the moment of charging, a passage is made between the spitzkasten and charging funnel by opening the cover, bringing forward the carriage and opening of the spitzkasten, these operations being performed by movements of the lever as shown in the drawings. The draft is produced by means of a ventilator One operator is necessary, who can attend to the charging and removal, and the costs with this furnace are so small that 0·01% ore can be treated profitably. The furnace, with condensers, costs 8,000 fr., and at Monte Amiata these furnaces are employed exclusively. In regard to the condensers and further treatment of the stuppe, see THE MINERAL INDUSTRY, Vol. VI., p. 578 and Vol. VIII., p. 490.

WORKING RESULTS OF THE CERMAK-SPIREK FURNACES AT SIELE, ITALY.

Length of Campaign.	Ore Treated. Kg.	Hg. %	Stuppe Treated.	Hg %	Total Quicksilver. Kg.	Quicksilver Recovered. Kg.	Quicksilver Loss Kg.	Quicksilver Loss %
Furnace No. 1.—12 Tons Capacity.								
From May 25, 1891, to April 21, 1892...	1,841,144	5·80	.....	.....	106,871·6	87,843·3	19,028·3	17·81
From May 10, 1892, to April 22, 1893...	1,865,479	5·45	12,229	25·24	104,788·1	101,434·6	3,350·5	3·20
From May 4, 1893, to May 27, 1894.....	2,243,627	5·43	11,436	25·84	102,541·8	99,622·6	2,918·2	2·85
From June 16, 1894, to April 20, 1895...	1,837,107	2·60	28,271	22·41	53,771·3	50,288·7	3,482·6	6·48
From Nov. 1, 1895, to Sept. 21, 1896....	1,755,864	2·31	39,110	1·99	41,340·7	38,877·3	2,463·4	5·96
From Jan. 21, 1897, to Oct. 31, 1897....	1,732,055	1·66	.....	.....	28,802·0	27,593·2	1,208·8	4·20
Total	11,275,276	3·76	91,046	14·45	438,115·5	405,663·7	31,414·8	7·18
Furnace No. 2.—Two Tons Capacity.								
From May 10, 1892, to April 22, 1893....	491,137	6·98	7,875	37·69	37,269·5	35,160·0	2,109·5	5·65
From May 4, 1893, to May 27, 1894.	701,884	5·42	15,643	33·39	43,441·9	41,160·3	2,281·6	5·52
From June 14, 1894, to Oct. 8, 1895.....	866,470	2·80	50,476	25·41	37,097·2	34,656 0	2,441·2	6·59
From Oct. 18, 1895, to Sept. 27, 1896....	616,845	4·29	12,559	30·06	30,072·6	27,891·8	2,180·8	7·26
From Oct. 22, 1896, to Aug. 20, 1897....	557,059	2·14	.....	.....	11,953·2	11,408·4	544·8	4·56
From Sept. 25, 1897, to May 31, 1899...	1,148,970	2·54	.....	.....	29,258·0	28,295·8	962·6	3·30
From July 18, 1899, to Nov. 14, 1901....	1,568,940	2·98	73,062	28·86	67,997·5	65.929·6	2,067·9	3·06
Total	5,949,310	3·55	159,615	28·74	257,089·9	244,501·5	12,588·4	4·90
Furnace No. 3.—20 Tons Capacity.								
From March 18, 1895, to Sept. 22, 1896.	6,374,390	2·26	.....	.....	144,525·3	126,190·1	18,335·2	12·69
From Nov. 12, 1896, to June 30, 1899...	12,509,720	1·56	.....	.....	195,617·6	191,098·8	4,516·8	2·32
From Nov. 1, 1899, to Oct. 31, 1901.....	10,615,120	1·59	.....	.....	168,907·0	165,428·2	3,478·8	2·06
Total	29,499,230	1·72	.....	.....	509,049·9	482,717·1	26,332·8	5·18
Total of three furnaces.....	46,723,816	2·45	250,661	23·55	1,204,255·3	1,133,919 3	70,336·0	5·85



SPIREK'S QUICKSILVER FURNACE.—DETAILS OF CHARGING DEVICE.



SPIRK'S QUICKSILVER FURNACE.

RARE ELEMENTS.

By Victor Lenher.

An element hitherto unknown except in combination has been prepared by Moissan by applying the electric furnace to the reduction of niobite. The new elementary metal is niobium and in many respects it resembles boron and silicon. Several rare earths whose elementary character has been repeatedly doubted have recently given undoubted proofs of complexity. According to Baskerville, thoria, one of the main constituents of the incandescent gas mantle, appears to break under certain fractionations into old thoria and a new body which is provisionally called "Carolinium."

The radioactive substances which possess the peculiar property of emitting light have been studied with the view of ascertaining the cause of their strange behavior. Thus far but little knowledge has been obtained of the reasons why they exhibit their characteristic properties, except that it be an inherent property of certain new elements whose properties are very little known at present. These elements—if they can be called such—seemed to be found in nature with other rare elements, as uranium and thorium, which also show unusual properties. The fluorescence of certain uranium compounds and the behavior of thoria in the incandescent mantle are so well known that they need no further comment, yet it is with these two elements that substances possessing radioactivity are found.

The use of liquid air as a cooling agent has enabled Pictet to obtain liquid oxygen from the atmosphere, thus rendering cheap oxygen a possibility. He shows 90% oxygen can be produced at 0·013 fr. per cu. m., or less than the selling price of ordinary illuminating gas. The production of oxygen at such a figure means a complete revolution in industrial processes; it would mean the use of the oxyhydrogen blowpipe as a commercial agent both for the economical production of a high temperature and for the cheap production of light with an incandescent lime or zircona medium. These results, coming as they do from Pictet, are of great weight.

As a result of the inquiries and investigation of the International Commission on Atomic Weights, it seems likely that O=16 will be universally accepted as the standard, at least for some time. Much expression has been given as to whether the standard should be O=16 and H=1·08 or H=1 and O=15·88. In all prob-

ability the two standard tables of atomic weights based on the respective values of O=16 and H=1 will be continued in use.

Argon, Neon and Helium.—In the evaporation of a large amount of liquid air a residue is obtained which consists of krypton, xenon, and argon. Argon is the most volatile and the gases are separated by Ramsay and Travers[1] by alternate evaporation and liquefaction. To obtain neon and helium the escaping gas from ar air liquefier is used. The gas which is mainly nitrogen is liquefied and air blown through it, the first portion to evaporate contains most of the neon and helium together with oxygen, nitrogen and argon. The oxygen and nitrogen are separated in the usual way and the neon and helium fractionally separated from the argon. Neon is obtained free from helium by several fractionations at the temperature of boiling hydrogen. The densities given are argon=19·96, krypton=40·88, xenon=64. Argon boils at —186°C., krypton at —151·7°C., xenon at —109°C. The spectra have been studied by Baly; that of neon is orange pink, krypton is pale violet and xenon is sky blue. These gases find no place in our present periodic table of the elements, but appear to form a series by themselves.

In studying the occurrence of nitrogen and helium in uranium and thorium minerals, Kohlschütter observed certain experimental data showing that helium is combined in these minerals. When samarskite is heated in carbon dioxide, helium is completely driven off. It has been impossible, however, to synthesize a helium compound. Dewar in his work at low temperatures, considers helium to have a critical temperature below 9° absolute scale and even when it finally liquefies, its evaporation will not give the absolute zero. To get 1° lower in temperature another gas would have to be found as much more volatile than helium as the latter is than hydrogen.

Barium.—By the electrolysis of a solution of barium chloride using a mercury cathode, Guntz[2] prepares barium amalgam which, when heated to 1,000°, gives metallic barium free from mercury. The metal is white as silver, soft as lead and melts at dull redness, while at bright redness it readily volatilizes. It oxidizes rapidly in the air, giving the white oxide, and like lithium and calcium it gives with liquid ammonia an ammonium compound which, however, is not very stable. Metallic barium easily decomposes water and alcohol.

Boron.—A number of new metallic borides have been obtained by Tucker and Moody,[3] who fused in the electric furnace an intimate mixture of boron with various elements. Borides of tungsten, chromium, zirconium and molybdenum were obtained, all being hard crystalline bodies of high specific gravity, high melting point and attacked by acids with difficulty. Orlow has examined a specimen of commercial boron from Merck and found smal ltransparent grains of boron trioxide, a little iron and about 9% of water. The latter was only expelled above 1,100°C. In 1895 Moisson observed that amorphous boron prepared by the commercial way, contained only 50% B, the remainder being hydride, nitride, boric acid and the sodium and iron borides. The element is conveniently prepared in the amorphous condition by heating borax with magnesium powder,

[1] *Proceedings of Royal Society*, 67, 329, 1901. [2] *Comptes Rendus*, 133, 872, Nov. 25, 1901.
[3] *Proceedings of Chemical Society*, 17, 1901, p. 238.

while the crystalline variety is obtained by dissolving this amorphous powder in a fused metal as aluminum, and obtaining it as crystals on cooling. Perboric acid is prepared by the electrolysis of an orthoborate. A solution appears at the anode which bleaches potassium permanganate and liberates iodine from potassium iodide.

Cæsium.—The mineral pollux, one of the chief sources of this metal, is decomposed by Chabrie with 100 times its weight of pure hydrofluoric acid. He prepares the acid sulphite by saturating the alcoholic solution of the carbonate with sulphur dioxide. The sulphite appears as white crystals, the thiosulphate as colorless needles and the dithionate as hexagonal plates. The bromide, iodide, acid fluoride, chromate and bichromate also appear as well-defined salts.

As a continuation of his work on cæsium, Wells[4] purifies cæsium salts by precipitation of the double chloride with lead tetrachloride. He uses less concentrated hydrochloric acid than Godeffroy. One-half to one-third of the total volume of hydrochloric acid answers very well as the solution can then be filtered through paper. To such a solution, antimony trichloride is added until no more precipitate forms. The precipitate is collected on a filter and washed with hydrochloric acid. To the filtrate from the antimony salt without concentrating, lead nitrate is added at the rate of from 2 to 3 g. per liter. Chlorine is passed in to saturation and, after standing a few hours, the liquid is decanted from the precipitate of Cs_2PbCl_6, which is usually colored dark green from antimony salts. The precipitate is boiled with dilute ammonia and the ammonium salt decomposed by boiling with nitric acid when the nitrate is formed which may be fused. The nitrate may be readily recrystallized. The carbonate is obtained by treating the nitrate with oxalic acid and fusing in a platinum crucible. The purest cæsium compounds are best obtained by crystallizing $CsCl_2I$. This compound is prepared by treating the nitrate with 10 parts hydrochloric acid (1 to 10) and the requisite amount of iodine, and dissolving just below boiling, from which latter the yellow salt crystallizes on cooling. One or two recrystallizations give a very pure product. This trihalide gives pure cæsium chloride by heating just below fusion. When cæsium nitrate is evaporated with strong nitric acid the last of the acid is expelled with difficulty, due to the formation of an acid nitrate. Cæsium forms two acid nitrates with one and two molecules of nitric acid respectively. It also forms a double nitrate with ferric nitrate and one with bismuth nitrate. Five double fluorides of cæsium and antimony, containing different proportions of the two simple salts, appear. These are of white color, soluble in water and are formed by dissolving cæsium carbonate and antimonious oxide in hydrofluoric acid and crystallizing the solution. Cæsium periodate, prepared by the action of periodic acid on cæsium carbonate, appears in white plates which are but sparingly soluble in cold water.

Cerium.—Sterba[5] prepares pure ceria by subjecting cerous nitrate, made from monazite by the method of Debray, to the oxidizing action of the electric current, which yields a perfectly pure cerium compound. The ceric oxide was colored from yellow to rose, due to the presence of nitride. When nitride is absent the oxide is pure white. Ceric oxide, heated in hydrogen, is incompletely reduced,

[4] *American Chemical Journal*, 26, 265, September, 1901. [5] *Comptes Rendus*, 133, 221, July 22, 1901.

Ce_2O_3 being formed. Zinc also reduces it. When fused with common salt, borax, or potassium sulphate, it appears in colorless, transparent cubes or combinations of cubes and octahedrons.

According to Bloxam,[6] the mass and weight of an incandescent mantle may be reduced from 0·60 g. to 0·35 g. and the ceria very much increased. These very desirable results are obtained by the addition of a substance which has a tendency to sinter, such as silica or an organic compound. The example given is: 45 g. thorium nitrate, 0·95 g. cerium nitrate, 20 g. ammonium nitrate, dissolved in 274 g. water and 11·2 g. of a dialyzed solution containing 2% SiO_2. A fabric made of No. 100 cotton containing 120 meshes in every turn of the knitting and five turns per cm. is impregnated with this solution and burned as usual.

Bleichrode[7] has patented a mixture for automatically lighting gas by soaking vegetable tissue in a concentrated solution containing 1 part thorium nitrate, 1 part platinum chloride and 0·1 part of cerium nitrate. The tissue is burned off, the ash molded into pellets and heated to redness.

Fluorine.—The monograph of Moissan on fluorine has recently appeared and shows that the isolation of fluorine was the result of years of patient painstaking work. Full details of the physical and chemical properties of the element have been worked out. When fluorine is free from hydrofluoric acid, the gas has so little action on glass that many chemical reactions can be readily observed. Moissan and Lebeau[8] have obtained the new gas, sulphuryl fluoride, by passing fluorine into sulphur dioxide in an apparatus so arranged that the two in coming into contact may immediately be combined by means of highly heated platinum. Unless such an arrangement is made, the union of the gases is delayed and then subsequently takes place with explosive violence. Sulphuryl fluoride boils at 52°, melts at 120°, is colorless, odorless and not very active. The determination of fluorine in a fluoride, decomposable by acid, as fluorspar, is effected by Burk[9] by treating 3 g. dry silica and 0·2 g. fluorspar with 40 c.c. concentrated sulphuric acid. The mixture is heated to from 120 to 135°, and the silicon fluoride conducted into potassium fluoride solution; potassium silicofluoride is completely insoluble in alcohol and is precipitated by adding an equal volume of alcohol. The precipitate is dried at 100°.

Gallium.—In their examination of atmospheric dust and soot from various sources, Hartley and Ramage call attention to the wide distribution of this element in aluminous minerals, in flue-dust from various sources, in atmospheric dust, and in many iron ores.

Hydrogen.—The physical properties of liquid hydrogen have been more carefully studied by Dewar, who finds by means of a helium thermometer that its boiling point is 20·5° on the absolute scale. The solid melts at 16°. Thus far the lowest temperature recorded is 14·5°. The latent heat of liquid hydrogen at its boiling point is 200 units, while that of the solid is 16 units. The specific heat of hydrogen between its melting point and its boiling point is 6, which is the highest of any known substance, and shows that it obeys the law

[6] English Patent No. 15,080.
[7] English Patent No. 22,388.
[8] *Comptes Rendus*, 132, 374, Feb. 18, 1901.
[9] *Journal of the American Chemical Society*, 23, 825, November, 1901.

of Dulong and Petit. Its surface tension at the boiling point is one-fifth that of water.

Hydrogen peroxides higher than the ordinary dioxide have recently been claimed. The hydrogen from palladium hydride gives oxidation products which oxidize indigo more rapidly than the ordinary dioxide. The treatment of persulphuric acid with potassium permanganate and the action of hydrogen dioxide on potassium permanganate in the cold gives products which are very energetic oxidants. It is very doubtful whether these are true higher peroxides.

Indium.—This element is characterized by an indigo blue line in the spectrum. It is best detected microchemically according to Kley as the double chloride with rubidium by adding a small fragment of rubidium chloride to a solution of indium hydrate in hydrochloric acid. Colorless rhombic octahedral crystals separate. The reaction is delicate to 0·00024 mg. indium. Cæsium chloride gives a more delicate reaction but the crystals are very small and indistinct. Ammonium salts should not be present in carrying out the test as ammonium indium chloride is soluble in hydrochloric acid. Indium may be separated from other metals as hydroxide. From the trivalent metals, the separation by ammonia is followed by treatment with ammonium carbonate in which indium dissolves and from which it can be precipitated by oxalic acid. When little indium is present, it is better to use the rubidium chloride separation. Renz quantitatively precipitates indium hydroxide by the addition of dimethylamine to the hot solution. This hydrate, like alumina and gold hydrate, is feebly acid and gives salts with metals like magnesium. Indium molybdate is a white voluminous precipitate obtained by the addition of ammonium molybdate to indium solutions; it can be used to separate indium from zinc. Indium forms alums with rubidium and cæsium and by boiling indium-cæsium alum in dilute solution, indium oxide is precipitated in pure condition. The physical constants of indium show it to have a valence of four and to resemble iron and aluminum, although it resembles the zinc group in that it forms an amalgam.

Iridium.—The separation of the platinum metals, as described in THE MINERAL INDUSTRY, Vol. IX., p. 572, has been much simplified by Leidie, especially for use in the commercial extraction of platinum and iridium. The ore is treated with hot aqua regia, evaporated to dryness, heated to 105 or 110°C. and dissolved in water. The solution is treated with sodium nitrite at 70°C. until neutral, sodium carbonate is added and chlorine passed through after filtering. The ruthenium and osmium pass off as volatile oxides. Instead of treating the solution with ammonium chloride which precipitates the platinum and palladium, the hydrochloric acid solution is made alkaline with soda and the two metals are precipitated by formaldehyde and may be separated in the usual way. The substitution of potassium chloride and the use of formaldehyde avoid the objectionable palladao- and platino-amines which are produced by ammonia, as well as the ignition necessary to drive away ammonium chloride, an operation which is attended with a great deal of trouble when operating on a large scale. The iridium and rhodium are separated either by potassium or ammonium chloride and chlorine, the iridium being precipitated.

Neodymium.—Matignon[10] has found that neodymium chloride deposits as

[10] *Comptes Rendus*, 133, 289, July 29, 1901.

$NdCl_3$, $6H_2O$ in rose-colored deliquescent crystals from hydrochloric acid solution at the ordinary temperature. The salt is very soluble in water. The concentrated solution dissolves neodymium oxalate and the insoluble oxalates of the other rare earths, and on cooling crystals of the chloro-oxalates separate. The hydrated salt is decomposed on drying. The anhydrous salt is prepared by transforming the sulphate into sulphide in hydrogen sulphide gas, then transforming the sulphide to chloride by means of hydrochloric acid gas. The anhydrous chloride is rose colored and fuses easily to a rose-colored deliquescent mass. This compound dissolves in water with a hissing noise. The metal may be obtained by treating the anhydrous chloride with sodium.

Niobium.—Moissan[11] has prepared metallic niobium from powdered columbite mixed with sugar carbon by heating the mixture 7 or 8 minutes in the electric furnace with a current of 1,000 amperes at 50 volts. All of the manganese and most of the iron and silicon were volatilized leaving a gray crystalline mass of niobium and tantalum containing 2·18 to 2·34% C. This alloy was dissolved in nitric and hydrofluoric acids and niobium oxide separated by the Marignac method. Eighty-two parts niobic acid were mixed with 18 parts sugar carbon, the mass mixed with turpentine and heated 3 to 4 minutes with a current of 600 amperes at 60 volts. The fused metal which was obtained is so hard it scratches quartz. It cannot be fused in the oxyhydrogen blowpipe but readily liquefies in the electric furnace. It burns in fluorine at 205°C.; chlorine gives the yellow chloride. Bromine attacks it at a higher temperature, while iodine is without action at the red heat. At 400°C. the metal burns in oxygen and at a higher temperature in air. Alloys of niobium are obtained with difficulty; sodium, potassium, and magnesium can be distilled over the fused metal without combining with it while only a small percentage of niobium combines with iron. While the metal does not decompose water, even at 600°C., at this temperature it burns in sulphur dioxide and nitric oxide. At a red heat phosphoric anhydride is reduced to phosphorus and carbon dioxide to carbon. Hydrofluoric acid attacks the metal but hydrochloric and nitric acids as well as aqua regia are without action. Boiling sulphuric acid is colored brown and at the same time niobic acid is precipitated. A mixture of nitric and hydrofluoric acids rapidly dissolves niobium.

Alloys of niobium and tantalum have been prepared by Smith and Hamilton,[12] by reducing columbite with carbon in the electric furnace and fusing the resulting matte with metallic copper, which forms a product resembling metallic copper. An analysis showed: copper, 95·01%; niobium and tantalum oxides, 2·01%; gangue, 2·57%. The matte resulting from the reduction of 100 parts columbite and 15 parts carbon was fused with an excess of metallic iron. The powder was brittle and steel gray in color and contained: Nb, 59·76%; Ta, 18·77%; Fe, 15·73%; W, 5·12%; gangue, 5·76%. A matte of niobium and tantalum, a matte of titanium from rutile, and an excess of metallic iron fused in the electric furnace yielded an extremely hard gray colored alloy which contained: Fe, 80·02%; Nb, 10·15%; Ta, 2·91%; Ti, 3·18%;

[11] *Comptes Rendus*, 133, 21, July 1, 1901.
[12] *Journal of the American Society*, 23, 151, March, 1901.

C, 1·99%; Si, 2·14%. A current of from 145 to 165 amperes at 35 volts was used in this work.

Levy[13] analyzes samarskite by fusing one gram of the mineral with six grams potassium acid sulphate. The cold mass is extracted with warm water leaving the silicon, niobium and tantalum as oxides. The filtrate is heated with hydrochloric acid and precipitated by ammonia and the filtrate boiled to reprecipitate any uranium oxide or alumina. The filtrate from this is examined for calcium and magnesium in the usual manner. The ammonia precipitate is dissolved in hydrochloric acid, the alumina separated by sodium hydrate, the rare earths separated as oxalates and converted into oxides. The iron and uranium are separated by means of ammonium sulphide and carbonate. The uranium is weighed as U_3O_8 and UO_2. The silicon, niobium and tantalum oxides are again fused with potassium bisulphate, the filtrate is treated as above and the residue treated with hydrofluoric acid, which removes the silica. The niobium and tantalum are separated by means of potassium fluoride and hydrofluoric acid. The silica is checked in the original mineral by determining it with hydrofluoric and sulphuric acids. The rare earths are separated by dissolving the ignited oxalates in hydrochloric acid with the aid of a little potassium iodide, the solution evaporated to dryness, the residue dissolved in a small quantity of water, treated with saturated potassium sulphate and allowed to stand for two days. The yttria solution is precipitated by ammonia, ignited and weighed. The cerium group precipitate of double sulphates is dissolved in hydrochloric acid, precipitated by ammonia, ignited, and weighed. A sample of samarskite thus analyzed gave: SiO_2, 2·86%; Nb_2O_5, 31·52%; Ta_2O_5, 16·63%; Fe_2O_3, 10·68%; Al_2O_3, 3·07%; U_2O_3, 12·13%; CaO, 3·34%; MgO, 0·1%; CeO_2, 1·65%; Yt_2O_3, 14·32%; insol. oxides, 0·79%; ignition loss, 2·48%. Total, 99·57%.

Nitrides.—Beilby and Henderson[14] have submitted various metals to the action of ammonia at high temperatures. Iron in the compact state, heated in a current of ammonia, is more or less completely converted into the nitride Fe_4N_2, the essential conditions being the presence of a large excess of ammonia and a temperature of from 450 to 850°C. The nitride is a silver-white body readily soluble in dilute hydrochloric or sulphuric acids. Heated to redness in hydrogen it is completely decomposed into iron and hydrogen. Pure iron is rendered hard and brittle as steel by absorption of small quantities of nitrogen. Tubes of malleable iron exposed seven days to ammonia at 700°C. becomes brittle as porcelain, while charcoal iron becomes so hard that it can be used as a drill. In a similar manner, Co_4N_2 is produced at 470 to 500°C. yielding a dull gray powder which in its properties resembles iron nitride. Ni_3N is formed at 400 to 600°C. It is black and resembles cobalt and iron nitrides. Copper is very sensitive to the action of ammonia at high temperatures, the nitride is easily decomposed by heating in hydrogen and can only exist within a very narrow range of temperature.

Osmium.—The use of osmium filaments in incandescent lamps has caused quite an active demand for this metal. Its price has been quoted during the year at $21 per oz., a slightly higher figure than gold. Welsbach has been able to

[13] *Analyst*, 26, 64, 1901. [14] *Journal of the Chemical Society*, 79, 1245, November, 1901.

reduce osmium to a filament and substitute it for carbon in incandescent electric lights. It withstands a higher temperature, is more durable and gives a higher illuminating power. The osmium lamps can be operated at 25 and 50 volts and show an efficiency of 1 Watt per candle power. It gives a light of from 2 to 200 candle power. Osmium is one of the older metals of the platinum group, it was discovered in 1803, and is found in nature associated with iridium and other of the platinum metals. The metal usually appears as a dark gray powder. One of the compounds which has been of commercial importance is the oxide which comes into trade as osmic acid. It is used as a black stain in optical apparatus.

Palladium.—S. Cowper-Coles[14a] describes a process of making non-tarnishable parbolic reflectors by the use of a silvered glass mold on which copper is electrolytically deposited, the metal and mold being subsequently separated by immersion in lukewarm water, the different co-efficients of expansion serving to separate them easily. Palladium is then deposited uniformly from an electrolyte of the double chloride of palladium and ammonium dissolved in a concentrated solution of neutral sodium citrate. By rapid rotation of the metal mold the deposit of palladium is very uniform, the thickness of the deposit being from 70 to 80 grains of palladium per sq. ft. of surface. Palladium is practically non-corrodable, and resists to a remarkable degree the heat of the arc light.

The hardness of palladium compared with other metals, as represented by the number of centigrams weight on a diamond point required to produce a scratch, is as follows: Electrolytic nickel 10, Sheffield plate 10, electrolytic antimony 9, electrolytic platinum 9, electrolytic palladium 8,electrolytic chromium or copper 7, electrolytic cadmium 4·5, electrolytic silver (burnished) 4, silver deposited chemically 2.

Radium.—The examination of the spectrum of radium and polonium shows a number of new lines which seem to belong to these bodies. Curie and Debierne show that while radioactivity is not produced by direct rays from a radium salt, it is communicated by the air from molecule to molecule from the radium salt to the body which is excited. It is possible to communicate radioactivity to distilled water by distillation of a radium chloride solution which has been allowed to stand several days, or by placing a radium salt solution and distilled water in separate dishes in a perfectly closed space. The same result is obtained by placing a celluloid capsule containing a radium salt in distilled water. The energy may be transmitted by radiation and by a kind of conduction passing through gases and liquids but not ordinarily through solids. Becquerel shows that secondary radioactivity consists of a portion not deviable by a magnetic field and easily absorbed; a portion which is deviable by a magnet and identical with cathode rays; and a portion not deviated by a magnetic field and very penetrating. It is worthy of note that radium rays cause skin wounds very similar to X-rays.

Hofmann has carefully studied radioactive lead from the mineral bröggerite which is a uranium, thorium and lead uranate. An analysis of this mineral from Raade near Moss in Norway, shows UO_2, 50%; UO_3, 27·83%; ThO_2,

[14a] *Electrochemist and Metallurgist*, April, 1901.

4·96%; yttria earths, 4·56%; Fe_2O_3, 0·46%; Bi_2O_3, 0·35%; PbO, 9·06%. The radioactivity of lead sulphate from bröggerite and other minerals may be increased by boiling it with a sodium carbonate solution converting the carbonate into chloride and crystallizing from water. The most soluble fractions are the most active. The active sulphate shows a blue fluorescence when exposed to cathode rays, and its spark spectrum shows a characteristic violet line. In many respects radioactive lead is chemically similar to ordinary lead. It may be precipitated as hydroxide, sulphide, sulphate, chloride, or iodide. The chloride is more soluble than lead chloride, while two sulphates appear which show the metal to have a valence of two and four. The atomic weight of radioactive lead is probably about 260.

Samarium.—In 1885 Crookes in his work on electric phosphorescence in vacuum observed a band in samaria which he called the "anomalous line" as it disappeared in presence of lime. Demarcay now gives the spectrum of a new oxide which shows no indications of the spectra of samarium, and only traces of gadolinium. The anomalous line of Crookes is the strongest line in this spectrum. The new lines are considered to belong to a new element which has been named europium. As an element samarium is not at all sharply defined and it would not be at all surprising to have its character much more simplified. Samarium carbide has been prepared by Moissan in the electric furnace and like a number of the carbides of the more poorly defined elements, on treatment with water yields a mixture of solid, liquid and gaseous hydrocarbons, the hydrocarbons being of the acteylene, ethylene, and methane series.

Selenium.—This element which forms a gaseous hydride has proved itself to be an interfering agent in carrying out the Marsh test for arsenic. The source of the arsenic in beer which caused the recent poisoning epidemic in England has been attributed to the impure sulphuric acid used in the manufacture of the brewing sugar. Berry[15] has observed selenium in various acids and other materials and finds that like arsenic, it has the curious property of distributing itself over many manufactures into which it may be brought into contact. It is demonstrated that cotton wool moistened with lead acetate will remove selenium in the Marsh test and the arsenic may be subsequently deposited uncontaminated. Perreau has shown that Röntgen rays act similarly to light on selenium, and Bloch has observed that the emanations from radioactive barium carbonate act on selen cells similarly to feebly diffused light, lowering the resistance materially. By the electrolysis of potassium selenate containing a little free selenic acid, Dennis and Brown[16] obtained a white solid which contained as high as 74·44% perselenate. The substance is a powerful oxidant, oxidizing manganese dioxide to permanganate and losing oxygen when the solution is warmed.

Silicon.—Ferrosilicon is now being produced on commercial scale at Meran in the Austrian Tyrol and in France by treatment of scrap iron, quartz and coke in the electric furnace. Five thousand one hundred and twenty K.W. hours are required for the production of a ton of 78% ferrosilicon. The selling price of the material is based on the silicon content; 21% sells at about $40 per ton.

[15] *Journal of the Society of Chemical Industry*, 20, 322, April 30, 1901.
[16] *Journal American Chemical Society*, 23, 358, May, 1901.

Silicon improves the physical properties of steel where little carbon is present and it is of value in casting steel. Iron silicide as well as those of a number of the metals have received considerable attention at the hands of Moissan and Lebeau and the latter has shown that commercial ferrosilicon may contain the three silicides $SiFe_2$, SiFe, and Si_2Fe. The silicon copper manufactured by the Cowles Electric Smelting & Aluminium Co., at Lockport, N. Y., is marketed at 34c. per lb. in 500 lb. lots. Silicon copper is successfully used as a deoxidizing agent in casting bronze, brass, and copper. It is broken into small pieces and added to the alloy or metal after the other ingredients are in the crucible.

Cobalt silicide, CoSi, similar to FeSi, is prepared by Lebeau in the electric furnace by heating 400 g. copper silicide with 40 g. cobalt for 4 to 5 minutes with a current of 950 amperes at 50 volts. It appears in prismatic crystals which are so hard that they easily scratch glass. It has a specific gravity of 6·3 and is difficult to attack by the ordinary reagents.

Tellurium.—Mathey[17] states that the presence of minute quantities of tellurium in bismuth renders the metal unsalable and it is necessary to remove every portion of the tellurium in refining crude bismuth. He worked up the alkaline residues obtained, and by means of hydrochloric acid and sodium sulphite obtained a specimen of crude metal weighing 25 kg.

The alloys of tellurium with lead and antimony have been studied by Fay and Gillson.[18] In all the alloys prepared, lead telluride is a common constituent. Its amount gradually increases as tellurium is added to lead until the whole mass is lead telluride, and then gradually decreases until the whole mass is pure tellurium. Tellurium forms a definite alloy with lead telluride but the latter does not form such a compound with lead. The antimony-tellurium alloys are in many respects similar to the lead alloys, the alloys being formed with tellurium and antimony telluride.

Carnot divides the Kalgoorlie telluride ores into sylvanite, a bitelluride of gold and silver having a crystalline texture, calaverite, a bitelluride analogous to sylvanite but less crystalline and containing less silver, and coolgardite, or sesquitelluride of gold, silver and mercury, in which these metals are in variable quantities.

The tellurides of Coolgardie, West Australia, occur in a schistose amphibolite, the upper parts of which carry free gold. The minerals are sylvanite, calaverite, petzite, and copper ore much like enargite in composition. In a number of the rich sulphide ores from the Hauraki gold fields in New Zealand, tellurium has been found, but it is always in the ores along with copper. Not sufficient has been found to indicate how it is combined.

I have questioned the chemical composition of the telluride ores[19] and have shown that all of the natural tellurides of gold precipitate metallic gold from solution when brought in contact with them. As a chemical compound cannot precipitate one of its constituents it is a question whether the tellurium and gold are chemically united in these minerals. In the mines in which the tel-

[17] Paper read before the Royal Society, March 14, 1901.
[18] Paper read before the American Institute of Mining Engineers, November, 1901.
[19] Paper presented before the American Chemical Society, December, 1901.

luride ores are worked, specimens of native gold are frequently found in the upper parts of the mine. The native gold is a pseudomorph after the tellurides and has doubtless been deposited by a gold-bearing solution coming in contact with the tellurides. Another striking point is that metallic tellurium quantitatively precipitates gold from solution and specimens of native tellurium frequently carry a small per cent. of gold.

The quantitative precipitation of tellurium is effected by Gutbier by means of hydrazine in neutral solution. The method is applicable to both tellurites and tellurates.

A series of determinations of the atomic weight of tellurium have appeared but all show that its atomic weight is higher than that of iodine and that tellurium still remains an exception to the periodic law.

Mylius[20] has shown that ordinary telluric acid, $H_2TeO_4 2H_2O$, when heated to 140°C. is converted into allotelluric acid $(H_2TeO_4)_n$. This variety has five times the conductivity of the ordinary acid and forms white precipitates with solutions of guanidine carbonate and albumen. In solution it slowly reverts to the ordinary acid. The physiological action of tellurium compounds have been carefully studied by Gies.[21] In many respects the action of tellurium in the body is like that of selenium, arsenic, and antimony. When tellurous oxide is inhaled it causes metallic taste, nausea, depression, and constipation, methyl telluride is excreted with the breath and skin, while methyl telluride itself when inhaled acts very similarly. Potassium tellurate has been used to reduce night sweats in consumptives, but on account of the obnoxious odor imparted to the breath the tellurates have not come into general use.

Thallium.—In the examination of atmospheric dust from various sources Hartly and Ramage have detected the presence of thallium. Pumice from Krakatoa contains this element, while lead chloride from Vesuvius also contains it. The detection of thallium is effected by Reichard by the use of a saturated solution of an alkaline picrate, a light yellow precipitate is formed. The test is delicate to about 0·5 per cent.

Thorium.—Baskerville,[22] in a paper on the complexity of thorium, announces a new element for which the name carolinium is proposed. Thorium hydrate was dissolved in hydrochloric acid and the solution exactly neutralized with ammonia. This solution was saturated with sulphur dioxide, yielding in a few minutes a basic sulphite, which was filtered off and ignited to oxide. The filtrate was precipitated by ammonia and ignited. The specific gravity of the oxide obtained in these fractions differ considerably. The sulphur dioxide precipitate had a density of 9·38, the soluble portion precipitated by ammonia had a density of 10·367 while the original oxide had a density of 10·1. By boiling the citrate solution, a precipitate is formed which when ignited has a specific gravity of 9·2 and a solution which when evaporated and ignited gives an oxide with a specific gravity of 10·5. The fraction of purest insoluble citrate shows the

[20] *Berichte*, 34, 2208, July 20, 1901.
[21] *American Journal of Physiology*, 5, 104, March, 1901.
[22] *Journal of the American Chemical Society*, 23, 761, October, 1901.

element to have an atomic weight of 223·2 while the other element contained if tetravalent would have an atomic weight between 260 and 280.

Metathorium oxide, according to Stevens,[23] is a variety of thorium oxide which has the same composition but different properties than the ordinary oxide. The hydroxide is less basic than the ordinary, it does not absorb carbon dioxide from the atmosphere and on standing in contact with water it is transformed into the ordinary hydrate. A recent analysis of monazite from New Granada shows 18% thoria, 25·02% ceria, 22·41% La_2O_3, 1·21% MgO, 2·13% CaO, 3·0% SnO_2, 28·23% P_2O_5, with traces of iron, zinc and sulphur.

According to Nernst there is no special catalytic action of the Welsbach mantle to which the high economy is due. As the material of the mantle radiates very little red light and few ultra red rays, it yields little energy in that part of the spectrum in which the maximum emission of heat usually takes place, the mantle is consequently enabled to absorb the full heat of the gas flame and thereby to radiate a relatively large volume of light.

Titanium.—The introduction of titanium into steel is said to increase its tensile strength. Steel containing 0·5% Ti is used for piano wire, needles and certain electrical purposes. Titanium steel thus far is largely confined to the experimental stage.

Brakes[24] modifies the Baskerville method for determining titanium by fusing 5 g. ore with an equivalent amount of sodium fluoride and potassium sulphate, in a platinum crucible, dissolving the fusion in 10% suphuric acid and filtering into a 500-c.c. flask; 100 c.c. of this solution is placed in a Nessler tube and 5 c.c. of hydrogen peroxide added and mixed thoroughly. A comparison test is made by placing 100 c.c. of 10% sulphuric acid in a second Nessler tube and adding the number of cubic centimeters of a standard ferrous sulphate solution equivalent to the amount of iron present in 1 g. of the ore, 5 c.c. of hydrogen peroxide are added and standard TiO_2 solution is added until the desired tint is obtained, the color being compared by reflected light. Great accuracy is claimed for the method.

Uranium.—Uranium ores are sold in Denver according to the percentage of uranium content: 10% ores are quoted at \$17·50 per unit, 10 to 15% ores at \$18 per unit, 15 to 20% ores at \$19 per unit, 20% and over at \$20 per unit. The ore finds a ready sale at these prices. A large quantity goes to France.

Kern[25] has made a detailed study of the technical estimation of uranium with the view of finding the most accurate and satisfactory method. Uranium can be separated from the copper group by means of H_2S in an HCl solution. From the third and fourth groups it is best separated by means of a saturated solution of sodium carbonate or by ether, followed by a saturated solution of ammonium carbonate. The separation from iron depends on the fact that ether extracts ferric chloride from an aqueous hydrochloric acid solution while uranyl chloride remains in solution. From the alkalies and alkaline earths, the best method of separation is the electrolysis of a dilute acetate solution in

[23] *Zeitschrift fuer Anorganische Chemie*, 27, 41, 1901.
[24] *Journal of the Society of Chemical Industry*, 20, 23, Jan. 31, 1901.
[25] *Journal of the American Chemical Society*, 23, 685, October, 1901.

presence of sodium acetate; hydrated protosesquioxide of uranium appears on the cathode as a black deposit and this is ignited to U_3O_8, which may be weighed. The separation by means of ammonia in presence of ammonium chloride is best effected by boiling 20 minutes when the yellow slimy precipitate of ammonium uranate becomes darker and filters more readily. This precipitate is ignited to U_3O_8. The most rapid determination of uranium is accomplished by reducing a sulphate solution with zinc, magnesium, or aluminum, and titrating with potassium permanganate in an atmosphere of carbon dioxide. The results obtained this way are as accurate as by the gravimetric methods. Kollock and Smith separate uranium from barium, calcium, magnesium and zinc by the electrolysis of solutions of the acetate, nitrate, or sulphate, but cannot separate it from chromium and iron this way.

Uranium amalgam is prepared by Férée by the electrolysis of uranous chloride using a mercury cathode and separating the poles by a porous diaphragm. When the amalgam is heated to 241°C. in vacuum, the mercury is driven off, leaving a pyrophoric metal which burns brightly in air. Uranyl nitrate may be prepared on a large scale by the solution of the pentoxide, prepared by igniting ammonium uranate, in nitric acid of a specific gravity of 1·32.

Aloy has ascertained that for the preparation of metallic uranium in the electric furnace it is only necessary to use 15 to 25 amperes, while Moissan used 500 to 800 amperes at 45 to 55 volts. Uranium red, a complex potassium sulpho-uranate has been made by Kohlschütter[26] by treating potassium uranate solution with hydrogen sulphide, filtering rapidly, digesting the mass with potassium carbonate and extracting with alcohol, carbon bisulphide and ether. to remove sulphur. When dry the substance is a carmine red powder. The ammonium and sodium compounds are also red and the barium compound is so stable toward carbon dioxide and hydrogen sulphide that it can be used as a pigment.

Vanadium.—There is very little demand for vanadium oxide in quantities by the steel manufacturers and the supply from the slags of the Creusot steel works in France, amounting annually to about 165,000 lb., is used as a mordant in dyeing. A large supply would admit of the use of vanadium in the manufacture of armor plate, projectiles and bronzes. H. Proctor Smith[27] has studied the extraction of vanadium from the standpoint of obtaining a ferrovanadium alloy to be used in steel-making. The ore treated is an impure lead vanadate from Spain, crushed to pass through a 0·125-in. mesh sieve and fused for 20 or 30 minutes with two parts sodium or potassium bisulphate. The fused mass is crushed and leached with water, the resultant solution is allowed to stand in contact with scrap iron, and the lead sulphate, silica and undecomposed ore separated. The iron is introduced for the purpose of insuring that the vanadium will be present as vanadic salt. The vanadium and iron hydrates are now precipitated gray or black in color by the addition of a 25% solution of caustic soda. The gelatinous precipitate is filter pressed, washed and dried, and contains about 18% V_2O_5 to 77·5% Fe_2O_3. To make a ferrovanadium alloy the reduc-

[26] *Annalen*, 14, 311, 1901. [27] *Journal of the Society of Chemical Industry*, 20, 1193, Dec. 31, 1901.

tion is effected in the electric furnace by carbon and aluminum or aluminum alone. A mixture of 8 parts dried oxides, 2 parts powdered charcoal and 1 part aluminum in small pieces subjecting to the action of the electric arc in a graphite crucible yields a brittle button of fine white granular fracture, which contains V, 16%; Fe, 70%; Si, 20% and Al, C, etc., 12%. A mixture of the oxides with granulated aluminum ignited by means of sodium peroxide and magnesium or aluminum gives a brittle yellow metallic button containing about V, 15%; Fe, 58%; Al, 26% and Si, 1·3%. When used in steel-making these alloys require the same care as ferrochromium or ferronickel, and they increase enormously the tensile strength and elastic limit of steel to which they have been added.

Yttrium.—By the fractionation of the crude oxides from gadolinite by means of their ethyl sulphates G. and E. Urbain[28] find that the gadolinium elements can be so completely separated that the yttria and ytterbia solutions do not show phosphorescent spectra. The atomic weight of ytterbium is given as 172·6 and that of yttrium as 88·6.

Zirconium.—In the extraction of lead from a specimen of euxenite from Brevig, for the examination of its radioactive properties, Hofmann and Prandtl[29] have found an earth in the sulphate residues whose properties indicate an unknown metal. The oxide is white, and cannot be reduced by hydrogen but when fused with potassium bisulphate becomes soluble. Alkalies give a white flocculent precipitate. From the analysis of the sulphate its atomic weight is about 17·8.

Boehm has patented[30] a glow body for use in the Nernst lamp, which is resistant to outer influences. Such a mixture consists of 90 parts zircona, 5 magnesia, 4 lime, 1 manganese sesquioxide. This mixture is made into a paste with a sugar solution and is squirted into threads or rods. In Nernst's early experiments magnesia was used as a glower. More recent experiments have shown zircona and the rare earths used in the Welsbach mantle are satisfactory. The Nernst lamp consists in using a refractory earth as an incandescent material, this substance being a nonconductor when cold but allowing the current to pass through after it is heated. The glower in the present lamp is heated by means of a thin porcelain tube wound with platinum wire. Automatic cut-outs throw out the heaters when the current is established through the glower. The lamp is thus automatically lighted now while in the earlier types outside heat was applied to heat the glower. The present design of lamps gives from 50 to 2,000 candle power and it is expected that the new lamp will meet a want, as the light given off closely approximates the quality of daylight and shows colors in their proper shades.

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[28] *Comptes Rendus*, 132, 136, January, 1901. [29] *Berichte*, 34, 1064, April 20, 1901.
[30] English Patent No. 12,241, June 15, 1901.

SALT.

THE total production of salt in the United States, including that used for the manufacture of alkali and heavy chemicals amounted in 1901 to 20,566,661 bbl., as compared to 20,738,729 bbl. in 1900. The leading salt producing States rank in the order of maximum production and percentage of output as: Michigan, 7,729,641 bbl., 37·6%; New York, 7,286,320 bbl., 35·4%; Kansas, 2,087,791 bbl., 10·2%; and Ohio, 1,153,535 bbl., 5·6%. These four States furnished 88·8% of the total United States output in 1901.

PRODUCTION OF SALT IN THE UNITED STATES. (IN BARRELS OF 280 LB.)

Year.	California	Illinois.	Kansas. (d)	Louisiana.	Michigan (c)	Nevada.	New York. (c)	Ohio and W. Virginia. (b)	Utah.	Other States. (c)	Total Barrels.	Total Short Tons.
1897.....	484,650	58,764	1,224,980	209,392	5,470,621	5,540	6,172,681	1,010,800	657,340	528,705	15,822,923	3,215,209
1898.....	667,298	57,796	1,810,809	120,300	6,728,005	5,325	7,625,809	1,044,036	121,429	515,592	18,756,394	2,625,895
1899.....	590,386	54,500	2,172,000	357,143	6,699,060	5,900	7,726,172	1,215,000	448,132	594,555	19,861,948	2,780,677
1900.....	455,271	55,000	2,350,000	386,744	6,845,685	5,786	8,123,550	1,688,286	267,857	560,550	20,738,729	2,903,422
1901.....	601,659	99,700	2,087,791	451,430	7,729,641	13,781	7,286,320	1,385,257	334,484	569,092	20,566,661	2,879,433

(a) Amount inspected. (b) Includes the production of Pennsylvania. (c) Includes salt used for the manufacture of alkali. (d) Output in 1900 is estimated.

Imports and Exports.—The imports of salt during 1901 were 403,465,946 lb. ($676,332), as against 415,775,592 lb. ($633,192) in 1900; the exports of domestic salt amounted to 18,865,247 lb. ($86,414) in 1901, against 15,021,861 lb. ($65,410) in 1900, and the exports of foreign salt were 3,699,411 lb. ($7,155) in 1901, as against 3,548,724 lb. ($3,907) in 1900.

California.—The production of salt in 1901 was 601,659 bbl., against 455,271 bbl. in 1900, an increase of 145,388 bbl. during the year.

Kansas.—The mines of Rice County, near Lyons, are equipped with channelling machines and compressed air drills, and are working an 18 ft. bed of salt by the pillar and chamber method. The salt is crushed, graded and shipped without refining. Late in 1901 the Hutchinson-Kansas Salt Co. began the sinking of a deep well to prospect as far as the drilling machinery will permit. The wells now average from 750 to 800 ft. in depth.

Louisiana.—The success of the Myles Salt Co., of Weeks Island, Iberia Parish, in sinking through the quicksand by the caisson method, has contributed not a

little to the possibilities of salt production in Louisiana. Steel and wood caissons were used until the salt bed was penetrated, when walls of the shaft were fused with blow-pipes and covered with pitch and asphalt overlaid with cement. The output of salt in the State increased from 386,744 bbl. in 1900, to 451,430 bbl. in 1901.

Michigan.—During 1901 Michigan increased its salt production by 883,956 bbl., as compared with 1900, thereby taking first rank in the salt producing States. The Solvay Process Co. completed its additional installations at Detroit in the latter part of 1901, and the Pennsylvania Salt Co. purchased land on the Detroit river, near the Michigan Alkali Works, at Wyandotte, for the purpose of erecting an electrolytic plant for the manufacture of alkali and bleach by the Bell patents.

New York.—The production of salt during 1901 showed a decrease of 837,230 bbl., as compared with 1900. The report of the National Salt Co. for the year ending December 31, 1901 shows $5,758,250 common, and $3,758,250 of preferred stock beside the 12,417·5 shares each of common and preferred stock deposited with the American Trust Co., of Cleveland, O., pending litigation with the United Salt Co. The accounts show profits as follows: From the New York Department, $290,581; from subsidiary companies, $28,052; dividends, etc., $156,465; total, $475,098. Deductions are: Loss on Michigan Department, $275,738; New York office, $160,445; total, $436,183, leaving a surplus of $38,915 for the year, which added to the surplus from the previous year made a total of $876,374. Total deductions were: $155,314 for 1900 profit not received; bonds of subsidiary companies paid, $40,000; dividends paid, $651,172; total, $846,486, leaving a balance at the close of the year amounting to $29,888. An entirely new Board of Directors and Officers were elected during the latter part of the year. Early in 1902 articles of incorporation of the Oatka Mining Co. were filed at Albany. The capital stock is $500,000, and the company proposes to compete with the National Salt Co.

Utah.—The output during 1901 was 334,484 bbl., compared with 267,857 bbl. in 1900. A discovery of a large body of rock salt was made near Gunnison, San Pete County, containing 98·88% NaCl, with impurities chiefly iron oxide. A plant manufacturing 2 tons per day has been started, and enlargements are contemplated during 1902.

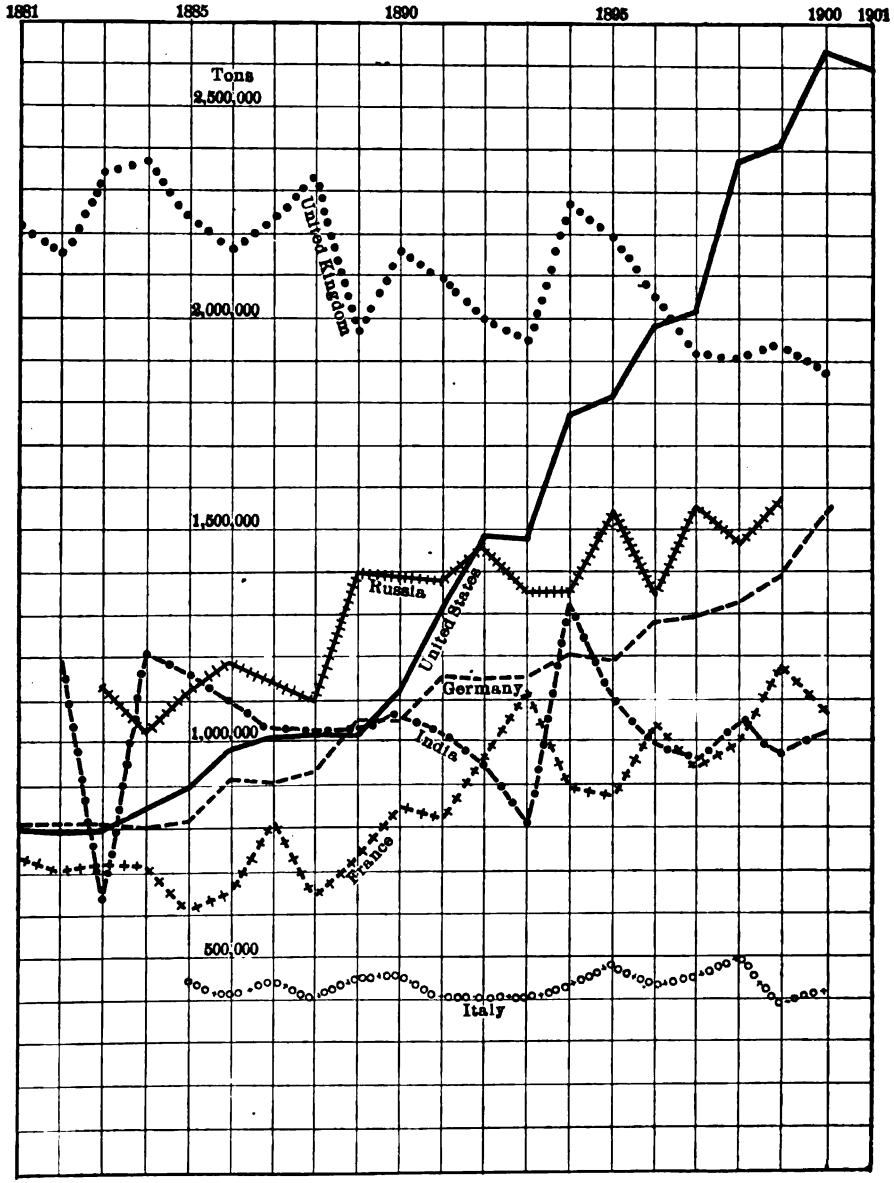
The World's Production of Salt.

Bosnia and Herzegovina.—The production of salt in Bosnia in 1900 amounted to 15,791 metric tons, while that of Herzegovina was 100,116 metric tons.

Canada.—The output in 1901 was 59,428 short tons, valued at $262,328, against 62,055 short tons, valued at $279,458 during 1900. Early in 1902 there were reports of the formation of a trust to consolidate the Canadian salt wells.

China.—The annual production of salt in the Tze-liu-ching district of China is estimated at 178,571 long tons. The district produces both oil and brine from wells which are sunk to a depth of from 2,200 to 3,300 ft. by means of churn drills, the operation taking in some instances as many as ten years to com-

plete. The gas is conveyed in bamboo pipes to the evaporating kettles made of cast iron, 4 ft. 9 in. in diameter and saucer-shaped, provided with extension sides



THE WORLD'S PRODUCTION OF SALT IN METRIC TONS.

made of iron plates luted with clay. This dish is set above a cup-shaped clay-lined hollow in the floor through the center of which the gas ascends.

Japan.—The output of salt in 1899 was 590,433 metric tons, which was produced chiefly from sea-water by solar evaporation only or by a combination of

spontaneous evaporation with artificial heating of the concentrated solutions. A small quantity of salt is produced from weak brine springs by artificial heating. One hundred and forty thousand workmen are employed in the Japanese salt industry.

Russia.—The principal deposits of salt in Russia are in the following Provinces: Tauria, Perm, Astrakan, Jekaterinoslaw, Charkow, Chersson, Orenburg, Caucasus, Ural, Turgai, and in the Transcaspian and Turkestan districts. The opening of the Perm-Kotlass Railway within the last few years has renewed the activity of the Urals which supplied all Russia, until discoveries of rock and lake salt in South Russia and the Volga region deprived Perm of its supremacy.

SALT PRODUCTION OF THE CHIEF COUNTRIES OF THE WORLD. (*a*) (IN METRIC TONS AND DOLLARS.)

Year.	Algeria.		Austria. (*d*)		Canada.		France.		Germany.	
1896.....	19,658	$85,121	308,932	$9,309,068	39,880	$169,693	1,042,614	$2,473,568	1,308,319	$4,416,952
1897.....	23,222	78,058	331,084	10,357,496	46,584	225,730	948,000	2,239,823	1,306,684	3,834,426
1898.....	21,300	86,000	341,959	10,795,700	51,796	234,520	999,283	2,115,120	1,370,341	3,954,743
1899.....	17,378	67,300	342,059	10,276,631	51,796	234,520	1,198,532	2,506,832	1,432,181	3,978,750
1900.....	18,325	76,288	343,844	10,165,131	50,296	279,458	1,088,634	2,415,973	1,514,027	4,027,500

Year.	Greece.		Hungary. (*d*)		India.		Italy. (*e*)	
1896.....	22,800	$344,280	180,133	$6,191,661	1,043,172	$1,097,909	29,274	$113,332
1897.....	20,421	308,357	171,711	5,375,788	937,888	975,260	31,525	117,504
1898.....	37,125	579,150	178,551	5,679,534	1,043,828	1,485,702	29,745	120,715
1899.....	22,411	336,165	182,193	5,479,782	977,240	1,324,748	28,842	64,418
1900.....	23,079	351,700	189,363	5,456,600	1,021,426	1,146,363	29,221	128,617

Year.	Japan. (*f*)	Russia.		Spain.		United Kingdom.		United States.	
1896.....	531,909	1,346,247	$3,026,000	521,751	$1,153,880	2,054,715	$3,333,065	1,995,017	$5,328,250
1897.....	621,731	1,551,894	2,711,077	508,606	1,159,294	1,933,949	3,104,490	2,009,625	3,898,556
1898.....	646,719	1,505,600	2,566,906	479,358	1,025,682	1,908,723	3,100,575	2,382,197	4,753,664
1899.....	590,433	1,681,362	2,767,168	598,108	1,091,133	1,945,531	3,220,870	2,522,610	5,437,941
1900.....	(*c*)	(*c*)	(*c*)	450,041	834,535	1,873,601	3,059,600	2,651,278	6,944,608

(*a*) From the official reports of the respective countries. For Austria, Hungary, Russia, Spain, and the United States, the production of all kinds of salt is given; Germany, rock salt and common salt; Greece, sea salt; France, rock and sea salt; Algeria, sea and rock salt; Italy, rock and salt from brine; United Kingdom, rock and brine salt; India, salt which is liable to British salt tax only, and does not include salt made in certain native States. (*b*) Not reported in the official statistics. (*c*) Statistics not yet published. (*d*) The high valuation of salt in Austria and Hungary is due to the government monopoly of production and high taxation. (*e*) Rock and brine salt only. About 400,000 tons of sea salt is made annually. (*f*) No value given.

SILICA.

UNDER this caption are grouped the various forms of silica that have a commercial or industrial value, including diatomaceous earth, tripoli, sand, silica brick, flint, pumice, sandstone and novaculite used in the manufacture of grindstones and whetstones. Sandstone for building purposes will be found under the heading "Stone," elsewhere in this volume.

Diatomaceous Earth and Tripoli.—Diatomaceous or infusorial earths were mined in the following localities during 1901: The Blue Hill, in Maine; on Troy Mountain, Troy, N. H., from which place the material is shipped to Keene to be calcined, bolted, and made up into cleaning and polishing powders; Framingham, Mass., where the product is burned and washed before it is marketed. In Calvert County, Md., infusorial earth was mined during the year. Hollow furnace brick and plastic asbestos cement is to be made from the infusorial earth recently uncovered near Wilmot, Va., and shipments were continued from the deposits of Esmeralda County, Nev. Deposits of infusorial earth of from 18 to 45 ft. in depth occur at Niederohe and Oberohe, northern Germany, from which large amounts are exported annually. The tripoli deposits of Murray County, Ga., were worked to some extent, and a limited quantity of the finely ground product was shipped. An unusual deposit of tripoli is that near Carthage, Mo., where it is found in a very compact but porous condition, so that it may be cut into shapes and used directly for water filters. The American Tripoli Co., of Seneca, Mo., made an unusually large production during the year, largely accounting for the increased value of the production for 1901 of both infusorial earth and tripoli, which amounted to a total of 4,020 short tons, valued at $52,950, as compared with 3,615 short tons, valued at $24,207 for 1900.

Extensive deposits of kieselguhr occur at Wyrallah, Lismore district, and at Barraba and Cooma, New South Wales, and experimental shipments to Sydney have been made; the demand, however, is limited and mining operations have made but little progress. A deposit of infusorial earth varying in thickness from 2 to 6 ft. and 600×1,000 ft. in area has been discovered at the bottom of Long Lake, Kings County, Nova Scotia. The material is light gray when wet, becoming almost white and very adhesive when dry. Its clay impurities render it unfit for use as tripoli. Another deposit occurs in Telegraph Lake in the same locality. Tripolite is produced in Nova Scotia by the Cairo Polishing Co., at River Dennys, Inverness County, and the Bass River Infusorial Earth Co., at Bass river, Colchester County, N. S., Canada, where it is found in a bed 3 ft. thick. It is purified by special treatment. The Victoria Tripolite Co., which makes a specialty of insulating material, has commenced extensive exploitation near St. Ann's, Victoria

County. The tripoli deposit of Fitzgerald Lake, near St. John, New Brunswick, is nearly white after calcination, and an assay gave: Soluble silica, 82%; insoluble silica in the form of impalpable quartz flour, 17·5%; clay, iron oxide, etc., traces. The tripoli is covered over by a deposit of grass and peat which is still forming.

Grindstones.—The value of the production of grindstones in the United States during 1901 was $580,703, against a value of $710,026 for 1900. The value of the imports during 1901 was $88,871. The amount of pulp stones produced in the United States during 1901 was 860 short tons, valued at $18,800, as compared with 553 short tons, valued at $12,495 during 1900. The price per ton decreased from $26 in 1900 to $22 in 1901. Pulp stones were produced in 1901 principally from the quarries at Empire, Peninsular, and Tippecanoe, O.

Pumice.—There was no output of pumice in the United States during 1901. The mines of the Chicago Pumice Co., in Utah, have been shut down owing to their inability to compete in price with the Lipari pumice, which is exported from Italy to the United States as ballast. A large deposit of pumice is reported from Sonoma County, Cal., and pumice sufficient to supply the demand of this country is found in Hawaii. The pumice industry is principally carried on in the Island of Lipari, Italy, the annual output amounting to about 8,000 metric tons. The pumice mixed with volcanic ash is found in a stratum of from 1 to 4 m. thick, extending over an area of about 6 square miles. It is overlaid by volcanic deposits of various character which have a thickness of from 4 to 8 m. At the present time over 200 mines are in operation, giving employment to 800 persons. As soon as the stone is brought to the surface it is sorted into grades, of which there are 16 recognized by the trade, determined by the size, color, and weight of the lumps. It is then forwarded to Lipari for manufacture.

Quartz and Flint.—The output of quartz or flint in the United States during 1901 amounted to 34,420 short tons, valued at $149,297. Of this total 51·3% was ground by the producers. There was a good demand and an increased price for flint during the year. The output of crude crystalline quartz during 1901 was 14,050 short tons valued at $41,500, which was used after grinding chiefly in the manufacture, with Japans and oil, of wood filler, although some is sold as tripoli, a considerable amount used as an abrasive in marble cutting, and a limited amount for the production of sandpaper.

French sea flint pebbles are gathered on the beaches between Havre and St. Valery-sur-Somme, a distance of a little over 100 miles. Those which are nearly spherical in shape are carefully selected and are used in the Alsing system of cylinder grinding, which is becoming so generally employed for pulverizing cement, pharmaceutical and chemical products, etc. The others are bought by the potteries for making ordinary porcelain ware, after being calcined, ground into a fine powder, and mixed with china clay. The yearly exports from France are about 13,500 tons, of which nearly one-half goes to the United States. The value of the selected pebbles varies from $8·52 to $10·21 per ton, in bags or barrels, f. o. b. at shipping port, while the pottery pebbles range from $1·27 to $2·92 per ton, f. o. b. in bulk. Ocean freight from Havre or Dieppe to New York averages 10 fr. ($1·93) per metric ton. Competition is keen with the Danish and other pebbles that are used for the same purposes.

Sand.—The bacteriological efficiency of sand as a filter for water is shown in the results obtained from the large filtration plant at Albany, N. Y. The weekly averages of bacteria in the unfiltered water ranged from 4,733 to 66,000 per c.c. and the percentage of removal ranged from 94·8 to 99·7%; the former figure was exceptionally low, the next lowest being 97·8%. Slow sand filtration will remove nearly all pathogenic bacteria, but will not remove all coloring matter from the water; the amount of the latter removable ranging from 25 to 50%. Odor is difficult to remove, and the results at Albany were not always effective, the odor being particularly noticeable in waste water from gas works.

PRODUCTION OF WHETSTONES AND SCYTHESTONES IN THE UNITED STATES.

Kind of Stone.	1898.		1899.		1900.		1901.	
	(a) Quantity.	Value.	(a) Quantity.	Value.	(a) Quantity.	Value.	(a) Quantity.	Value.
Hindostan (finished product)	275,000	$8,225	325,000	$9,750	260,000	$10,000	(c)	(c)
Indiana sandstone (finished product)	100,000	2,000	91,000	1,820	70,000	1,750	(c)	(c)
Arkansas stone ("rough rock")	40,000	1,600	60,000	2,400	50,000	2,000	(c)	(c)
Washita stone ("rough rock")	350,000	4,575	350,000	4,575	360,000	5,400	(c)	(c)
Miscellaneous oilstones (b)	.....	2,500	.....	4,000	.....	7,065	(c)	(c)
New Hampshire (Indian Pond, etc.)	13,000	35,750	13,000	35,750	} 18,000	54,000	(c)	(c)
Vermont (Lamoille, etc.)	5,000	17,500	5,000	17,500			(c)	(c)
Ohio and Michigan grit	15,696	36,100	.....	39,425	.....	5,659	(c)	(c)
Total	.....	$107,990	.....	$115,220	.....	$84,874	.....	$158,300

(a) Quantities given for Hindostan, Indiana, Arkansas and Washita stones and miscellaneous oilstones are pounds; for New Hampshire and Vermont scythestones, and Ohio and Michigan grit the quantities are number of gross. (b) Including Queer Creek, Chocolate, etc., estimated. (c) Detailed statistics not available.

Ferrosilicon.—The 7,830 calories liberated by ferrosilicon, as against 2,473 calories by carbon, when both are present (1% of either) in iron in process of Bessemerization to steel renders the use of the ferrosilicon in special processes of steel manufacture which deal with small quantities, far preferable to that of carbon alone, as the steel is not brittle unless there is also an excess of carbon. The metallurgical value of ferrosilicon increases with the percentage of silicon present. Ferrosilicon is being manufactured from scrap iron, quartz and coke at Meran, Germany, and at several carbide works in France. The product contains 77·5% Fe and 21·5% Si, and costs at Meran, $40 per metric ton, the yield in the electric furnace being one ton per 5,000 K.W. hours. The selling price of 10% Si in ferrosilicon is about $36 per metric ton, and that of 25%, $60 per metric ton, each 1% additional from $2 to $2·40 extra per ton. The use of Martin slags assaying SiO_2 50·42%, Al_2O_3 2·26%, FeO 34·1%, MnO 9·42%, CaO, MgO, etc. 3·3%, when mixed in the proportion of 1,680 kg. of slag and 600 kg. of 80% C. coke, yielded ferrosilicon containing 23·8% Si. There was produced in 110 hours, 4,090 kg. of material with a consumption of 5,380 K. W. hours per metric ton. The mixture used for the manufacture of ferrosilicon in the Styrian blast furnaces at Meran is 1,000 parts of forge iron scales, 410 parts of quartz, and 940 parts of coke. The electric furnaces use 1,000 iron scales, 410 quartz, and 398 coke; the percentages of useful elements in the raw material being Fe 71·9%, SiO_2 91·3%, C 63·9%.

SLATE.

THERE was an increase in the production of slate in 1901, the output being 1,304,379 squares of roofing slate, valued at $4,114,410 and $673,115 slate manufactures, against 990,036 squares ($2,885,153) of roofing and $502,051 of manufactures in 1900. The active demand in foreign markets had a buoyant influence on the industry during 1901, and the promise for 1902 is even better; the domestic trade also showed an increase in volume. The prices obtained for roofing slate were much better than in the preceding year, being more than in 1899, as the producers abided more closely by their established schedule of rates, the average price per square for the entire country being $3·15, against $3·01 in 1900, and $3·14 in 1899.

PRODUCTION OF SLATE IN THE UNITED STATES. (*a*)

States.	1900.				1901.			
	Roofing Slate. Squares.	Value.	Other Mfrs. Value.	Total Value.	Roofing Slate. Squares.	Value.	Other Mfrs. Value.	Total Value.
California	3,500	$26,250	*Nil.*	$26,250	2,500	$18,608	.....	$18,608
Georgia	*Nil.*	.....	*Nil.*	*Nil.*	800	3,000	.....	3,000
Maine	19,549	88,988	$46 905	135,893	20,791	111,295	$91,030	202,325
Md., Pa. (Peach Bottom)	24,384	114,869	*Nil.*	114,869	*b* 20,153	104,781	1,017	105,798
Pa. (Chapman's Quarries)	27,720	95,857	448	96,335	853,028	2,591,625	392,639	2,984,264
Pennsylva. (other districts)	563,014	1,577,614	358,849	1,936,463				
Vermont and New York	307,884	887,844	87,849	925,693	345,977	1,076,122	187,029	1,263,151
Virginia	42,965	189,701	5,000	144,701	53,630	178,979	.....	178,979
Other States	*e* 1,000	*e* 4,000	*e* 3,000	*e* 7,000	7,500	30,000	.....	30,000
Totals	990,036	$2,885,153	$502,051	$3,387,204	1,304,379	$4,114,410	$673,115	$4,787,525

(*a*) Not including slate pigment. (*b*) Peach Bottom included in Pa. (*e*) Estimated.

NOTE.—The production of slate pigment, including Baraga graphite and various kinds of mineral black, in 1900 was 6,617 short tons, valued, after grinding, at $72,787, against 4,911 ($50,338) in 1899. In 1901 the quantity of slate pigment produced in the United States is included under amorphous graphite, given elsewhere in this volume.

Export Trade.—The value of the roofing slate and slate manufactures exported during 1901 amounted to $898,262, as compared with $950,543 in 1900. The greater bulk of the shipments were to the United Kingdom via New York or Philadelphia.

The exports of roofing slate again showed a decrease in value due to the settlement of labor difficulties with the old, and the opening of new quarries in Wales. The exports to Australasia, however, increased, as they have done for several years past, by about 12%. New York, Philadelphia, Baltimore and Boston ports shipped the larger part of the slate exported to Denmark during the year, which country received roofing slate to the value of $43,344 in 1901, against $25,437 in 1900.

Market.—A short supply of rough slate at quarries at different times during the year, due to the heavy domestic consumption, resulted in premiums being paid on specified deliveries. Roofing slate of first-class quality sold f. o. b. quarry in commercial sizes as follows: Maine, $4·80 to $7; Peach Bottom, $4·75 to $5·35; Pennsylvania Bangor No. 1, $3·25 to $4·50; Bangor Ribbon, $3 to $3·50; Albion or Jackson Bangor, $2·85 to $3·25; Lehigh, $2·75 to $3. New York-Vermont prices were: Sea Green, $2 to $3; unfading green, $3·25 to $4·25; red, $8·50 to $10·50. Mill stock showed increased competition and irregular prices.

Arkansas.—The Memphis Slate Co., organized in 1900 to operate slate quarries at Blue Mountain and Little Rock, produced no slate during 1901, but considerable development work is reported. Slate is reported from localities in Montgomery, Saline, Pulaski and Polk counties.

California.—Although the production in 1901 amounting to 2,500 squares, was below that of 1900 amounting to 3,500 squares, interest is steadily increasing. Kelsey and Placerville, in Eldorado County, produce most of the roofing slate, which is blue-black in color with good cleavage, although there are small quarries at Merced, in Mariposa County.

Maine.—The production of roofing slate increased slightly during the year, while the price increased considerably, being $5·35 per square in 1901, against $4·77 per square in 1900. The value of the milled slate increased from $88,988 in 1900, to $91,030 in 1901.

Maryland.—Several new companies were formed during the year, and although the production of both roofing slate and milled slate was less than in 1900, the demand and market were good, and manufacturers are looking forward to an increased production in 1902.

New Jersey.—The operations in the vicinity of Newton were very active in 1901 and the production increased from 3,600 squares in 1900 to 7,500 squares in 1901. This slate belt is a continuation of the blue-black slate belt of Pennsylvania and Maryland. The New Jersey Slate Co. made extensive improvements at its Newton quarry during the year, consisting in the installation of a new boiler and other labor saving machinery.

Pennsylvania.—During 1901 Pennsylvania produced 62·33% of the slate mined in the United States, which was a slight decrease from the proportions of 1900, showing that the outside production is increasing at a greater rate than Pennsylvania, although the home production registered a very large increase over 1900. The value of the output during 1901 was $2,984,264, against $2,713,598 in 1900. The gain was in the output and value of roofing slate, which was 853,028 squares, valued at $2,591,625 in 1901, against 788,571 squares, valued at $2,277,192 in 1900, an increase of 64,457 squares during the year. The average value per square was $3·038 in 1901, against $2·887 in 1900. The value of the milled stock was $392,639 in 1901, against $436,406 in 1900, a decrease amounting to $43,767 in value for the year.

Vermont and New York.—The output of roofing slate in New York State increased from 7,713 squares, valued at $58,360 in 1900, to 15,786 squares, valued at $91,805 in 1901. The value of milled stock increased accordingly, the total

value of all kinds of slate being $62,755 in 1900, against $100,960 in 1901. The value of the roofing slate quarried in New York varies from $2 to $10 per square, the higher figure being caused by the small output of red slate, which is produced in no other State in the country. In 1901 Vermont produced 24·27% of the total slate of the United States during that year. In 1901 the total value was $1,162,191, an increase of $244,729 over 1900. The production of roofing slate was 330,191 squares, valued at $984,317, against 282,820 squares, valued at $795,474 in 1900. The smaller companies still held their prices through the selling agency established by them in 1900. The introduction of labor saving devices, notably by the Auld & Conger Co., of Cleveland, Ohio, who are the largest operators on the Poultney slate belt, has had much to do with placing the industry on a firm and economical basis. Among the improvements installed by the Auld & Conger Co. is an anchorage for the cables used to haul the slate from the pit. This anchorage consists of a heavily weighted car to which the cable is attached, and which travels on a track shaped to the segment of a circle, thus permitting a range of working of 50 ft. on either side of the normal line of a straight away cable. The saving in time by the use of this device will be appreciated by those who have been compelled to shift the bolthead anchorage of the incline, to accommodate some point perhaps but temporarily needing attention. This company has direct communication with the railroad three miles distant by means of an overhead cable tramway, and its self dumping waste rock rigging and system of providing splitting rock for the slate making sheds permits the most economical handling possible.

Virginia.—The output of roofing slate during 1901 was 53,630 squares, valued at $178,979, against 56,365 squares, valued at $185,211, a slight decrease in production during the year, but the decrease of 2,735 squares in output was somewhat compensated for by the increased average value per square, which was $3·33 in 1901, against $3·28 in 1900.

New Caledonia.—The slate deposits at Wagap and Manghine in New Caledonia, are said to be of excellent splitting quality, and the seams are very large.

Newfoundland.—The Wilton Grove slate quarry at Smith's Sound was very active in its operations during 1901, with the result that 2,000 tons of slate (equivalent to 6,000 squares) valued at $22,500 was produced during the year, against 600 tons (equivalent to 1,800 squares), valued at $10,800 during 1900. All of the 1901 production was exported to England. The slate is made in two sizes, 10×20 in. and 12×24 in., the former size being exported to Newcastle, and the latter to London. A stone steamship pier has been erected on the waterfront, enabling direct shipment of the finished product. About 50 men are employed, and Ingersoll steam drills are in use, the slabs being hoisted from the quarry by derricks. The slate is largely a dark purple in color, but some seagreen is also found. Several new deposits were located during the year.

United Kingdom.—The total quantity of slate produced in the United Kingdom during 1900 was 585,859 tons (about 1,757,577 squares), valued at $7,336,613, of which all but about 10% was consumed in the United Kingdom, beside the large importation from Newfoundland and the United States.

SODA AND SODIUM SALTS.

THE production of soda in the United States for the year 1901 is estimated at 480,000 metric tons, as compared with 390,000 tons for the year 1900. The above figures cover production in all the usual forms, reduced to the basis of 58%.

There have been various changes in the products or capacity of the several works producing the soda products mentioned in THE MINERAL INDUSTRY, Vol. IX., the principal ones being as follows: The Michigan Alkali Co. suffered from a disastrous fire in December, 1901, which destroyed the main building of the No. 1 soda ash plant. This plant was being run at the time to its full capacity, and its destruction involved a loss estimated at upward of $300,000. The company is now engaged in reconstructing its plant, and expects to have it in operation about the close of 1902. In addition, this company is building a battery of coke ovens for the purpose of supplying its works with coke and by-products. The Columbia Chemical Co., at Barberton, O., went into operation the latter part of 1900, producing soda ash. The operation of their soda ash plant has continued throughout the year 1901, and in the course of the year it has also commenced the production of caustic soda. The Frasch Process Soda Co., of Cleveland, O., has been in operation during parts of the year 1901. This plant is a small one, the output being something less than 30 tons per day, and it is said to be on too small a scale to be profitable. The Mathieson Alkali Co., of Saltville, Va., continued in operation throughout the year, producing soda ash, caustic soda, and sodium bicarbonate. Alterations and additions to the plant have been in progress for two years and the plant is said to have been more or less entirely remodeled. Among the improvements has been the building of a wire rope tramway for bringing the limestone from a point about 3 miles from the works, where quarries have been opened. The Solvay Process Co., of Syracuse and Detroit, has continued the installation of additions to its plant at Detroit begun during the year 1900. These additions were largely completed during 1901, and the additional output from their operation was felt in the latter part of the year. Further, 30 Semet-Solvay coke ovens have been built at Detroit for the purpose of supplying ammonia and coke for the use of the works. These ovens were put in operation in the last quarter of 1901. The American Alkali Co., which has been operating a small electrolytic plant at the Sault Ste. Marie, on the Canadian side, has become involved in somewhat intricate legal difficulties. The points at issue originated with the promoters of the company and their dealings with the Commercial Development Co., of England, of whom they bought the rights to use the Rhodin system. The Acker Process Co., of Niagara Falls, N. Y., has been in operation throughout the year 1901 on a small scale, producing caustic

soda and bleaching powder by the electrolysis of fused salt. It is reported that they have had some difficulty with the bleach produced, but that they have now made arrangements by which these difficulties will be overcome. The Castner Electrolytic Alkali Co., at Niagara Falls, has had under way during the year 1901 an enlargement of its plant which will enable it to use 6,000 H.P. in the production of caustic soda and bleach. Its first installation, which has been in operation for about two years, utilized 2,000 H.P. It is expected that the additional plant will begin producing in the latter half of 1902. The Pennsylvania Salt Manufacturing Co. has purchased land on the Detroit river, near the works of the Michigan Alkali Co., at Wyandotte. On this property, which has a large river frontage, it is erecting an electrolytic plant for the production of caustic soda and bleach. The company has acquired American rights in the patents granted to George Bell and George W. Bell, of Liverpool. It is said that they expect to turn out 100 tons of caustic and 150 tons of bleaching powder per week, and if the venture is successful four similar units will be added. There was a continuance during the year of the increased output of natural soda in the West, and it is estimated that during 1901 there was produced from this source 15,000 tons of soda in its various forms. The Occidental Alkali Co., of Hawthorne, Nev., which produced a small quantity of natural sodium carbonate salt during 1900, made no production during 1901. In addition to the production of the soda products mentioned above, there was imported from English makers approximately 15,000 tons of soda products on a basis of 58% in the forms of ash, caustic, bicarbonate and sal soda. This, as will be seen, is a radical reduction in imports from the year before. Furthermore, there has been a small exportation of soda products from this country to various points, notably to Great Britain. These have not been of any considerable quantity and have tended to decrease in the latter part of the year. It is thought that there was not sufficient profit in the business to make it attractive.

IMPORTS OF SODA PRODUCTS INTO THE UNITED STATES.

	1897.		1898.		1899.		1900.		1901.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
		$		$		$		$		$
Soda, nitrate..	212,721,600	2,810,187	330,386,560	2,298,240	328,142,080	3,486,313	407,921,920	4,935,520	467,440,960	5,999,098
Soda, bicarb...	965,669	13,992	280,988	5,794	162,398	5,219	133,137	4,509	(b)	(b)
Soda, caustic..	57,742,392	998,318	24,981,873	354,270	13,363,529	186,006	8,403,749	150,530	3,812,847	94,303
Soda ash (a)...	154,656,060	1,122,867	73,064,707	447,119	57,053,837	425,205	73,815,425	613,379	31,415,788	276,261
Oth'r soda salts	7,927,145	100,980	23,354,295	256,958	26,340,840	355,502	20,351,801	255,293	14,491,559	189,543
Lime, chloride.	109,176,451	1,460,799	108,462,828	1,229,978	123,582,061	1,203,364	132,510,478	1,524,205	117,510,359	1,673,190

(a) Including sal soda. (b) Included in other soda salts.

Market Conditions.—The average monthly price of domestic 58% ash per 100 lb. in lots of 50 tons or more f. o. b. works, is given in the following table:—

Year.	Jan.	Feb.	Mch.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Average.
1898.....	53·75	51·25	53·75	50·50	57·50	57·50	51·50	52·50	50·00	50·00	57·50	57·50	54·35
1899.....	57·50	59·20	62·50	66·50	67·50	63·75	68·75	70·00	71·75	80·00	82·50	83·50	69·45
1900.....	86·66	87·50	87·50	82·50	82·50	82·50	82·50	82·50	77·50	77·50	72·50	75·50	81·43
1901.....	80·00	80·00	74·00	80·00	78·75	77·50	80·00	76·50	75·50	77·50	78·50	85·00	78·60

Domestic bicarbonate of soda sold at 95c.@$1·10 per 100 lb. f. o. b. works, as compared with $1·065@$1·375 in the previous year. Extra grades remained unchanged at $3·25@$3·50 per 100 lb. f. o. b. works, less the usual discounts. Foreign ordinary grades brought $1·375@$1·75 per 100 lb. in New York.

Domestic caustic soda sold at $1·70@$1·95 per 100 lb. f. o. b. works, while foreign brought $1·85@$2·50 per 100 lb. in New York. Contracts for 1902 and 1903 were made at $1·85@$1·925 f. o. b. works. There was a good sale for this article among glass makers and mercerized goods manufacturers, but the imports were considerably less than in the preceding year.

Domestic soda ash in bags sold at 70@85c. per 100 lb. f. o. b. works for 58%, and 80@90c. for 48%. The market showed more strength in the latter part of the year owing to the destruction by fire of the plant owned by the Michigan Alkali Works and also to the depletion of stocks. Foreign soda ash was quoted at 85@87·5c. per 100 lb. in New York.

Domestic sal soda was quoted at 50@55c. per 100 lb. f. o. b. works in the East, and foreign at 65@67·5c. in New York. These prices are much lower than those ruling in 1900, the decline being caused by the competition among manufacturers, although the imports were less.

Bleaching powder of domestic make was quoted on the basis of the prices ruling for imported material, which were $2 for prime Liverpool and $1·75@$1·875 for Continental brands on contracts. New contracts for 1902 were made in the last quarter of 1901 at $1·75@$1·90 for prime Liverpool, and $1·70@$1·85 for Continental makes.

Natural Sodium Carbonate.—The production of natural sodium bicarbonate reduced to a basis of 58% ash during 1901 was about 15,000 short tons ($197,000), as against 14,100 short tons ($195,300) in 1900. The production continues to come from California and Nevada.

Sodium and Potassium Chlorates and Hypochlorites.—A review of these industries during 1901 is given under the caption "Potash and Potassium Salts," elsewhere in this volume.

Sodium Nitrate.—Chile Saltpeter.—The production of sodium nitrate in Chile during 1901 was 1,417,806 long tons, as compared with 1,473,091 long tons in 1900, a decrease of 55,285 long tons due to the rigid restriction of output by an agreement dated April 1, 1901, entered into by the principal producers. The combination on April 1, 1901, allotted the production for the year ending March 31, 1902, on an exportation of 31,273,000 quintals, with a subsequent agreement that but 75% of this amount should be exported during the succeeding 9 months. Good dividends were paid during the year by many oficinas, due to the utilization of the costras, ripios, and cuevas caliche formerly wasted. The cost of production has, however, decreased but little, due to the extra care taken with shipments. The report of the Salar del Carmen Nitrate Syndicate for the year ending December 31, 1901, is as follows: Gross receipts, £47,320 ($236,600), showing an increase of over 37%, as compared with 1900. After providing for the debenture interest and redemption account there was a surplus of £26,076 ($130,380). A dividend of 10% has been paid and £15,000 ($75,000) carried to reserve account, while £3,000 ($15,000) has been written

off for depreciation of plant. The output of the plant was again fixed at 600,000 quintals, and according to the report the cost of production should not exceed 4s. 8d. ($1·12) per quintal. It is estimated that the small nitrate companies averaged profits of from 24 to 42c. per quintal (about from $5·15 to $9·18 per long ton) during 1901, while the larger companies, with more opportunity for economy, earned larger dividends proportionately. A description of the Chilean sodium nitrate industry may be found in THE MINERAL INDUSTRY, Vol. IX., p. 596, *et seq.*

Sodium.—There are several works manufacturing metallic sodium in the United States, among them the Niagara Electro-Chemical Co., of Niagara Falls, N. Y., but no statistics of production are available. It is reported that several tons per week of potassium cyanide are manufactured at Niagara Falls by means of metallic sodium. Sodium peroxide in quantity is also manufactured at Niagara Falls, N. Y.

THE IMPROVED AMMONIUM CHLORIDE DISTILLER FOR A 100-TON SODA ASH PLANT.

BY JOHN R. WATSON.

THE distillers for the production of ammonium from ammonium chloride liquors in ammonia soda works vary considerably in detail, though in principle they are much the same.

The original design of an efficient ammonium chloride liquor distiller must be credited to Dr. Ludwig Mond, and the improved apparatus shown in the illustration, Fig. 1, on the following page, is a development of the type described in Lunge's *Sulphuric Acid and Alkali,* Vol. III., p. 111.

The most important improvements have been made along the following lines:—

1. In the proportion of the areas of the component parts.
2. In the distribution of the descending liquors.
3. In the form of the distiller portion, which comprises the lower compartments Nos. 1 to 11.
4. In the form of the diaphragm plates, and
5. In the location of the inlet and outlet pipes.

While all of these improvements have resulted in a very efficient apparatus, perhaps the one of most importance is the better location of the inlet and outlet pipes. The diaphragm plates, as shown in the cross section, Fig. 1, are in the form of an ellipse, which have proven the most satisfactory of all the various forms tried. The scale in the compartments assumes this shape. Total height is 91 ft.

Considering the requirements to be fulfilled in the distiller in which the ascending gases travel in a direction opposite to the descending liquor, a good rule to ascertain the proper area of the gas passages above the diaphragm plates and between them and the hood plate, is that each area shall be at least three times the area of the gas passage, and that the diameter of the hood plate at the point of denticulation shall be at least 70% of the diameter of the distiller. It should also be noted that the heater compartments of the distiller, shown in the illustration by Roman numerals I to XX, are of what may be termed the "bubble and spray" type. In all there are 33 compartments.

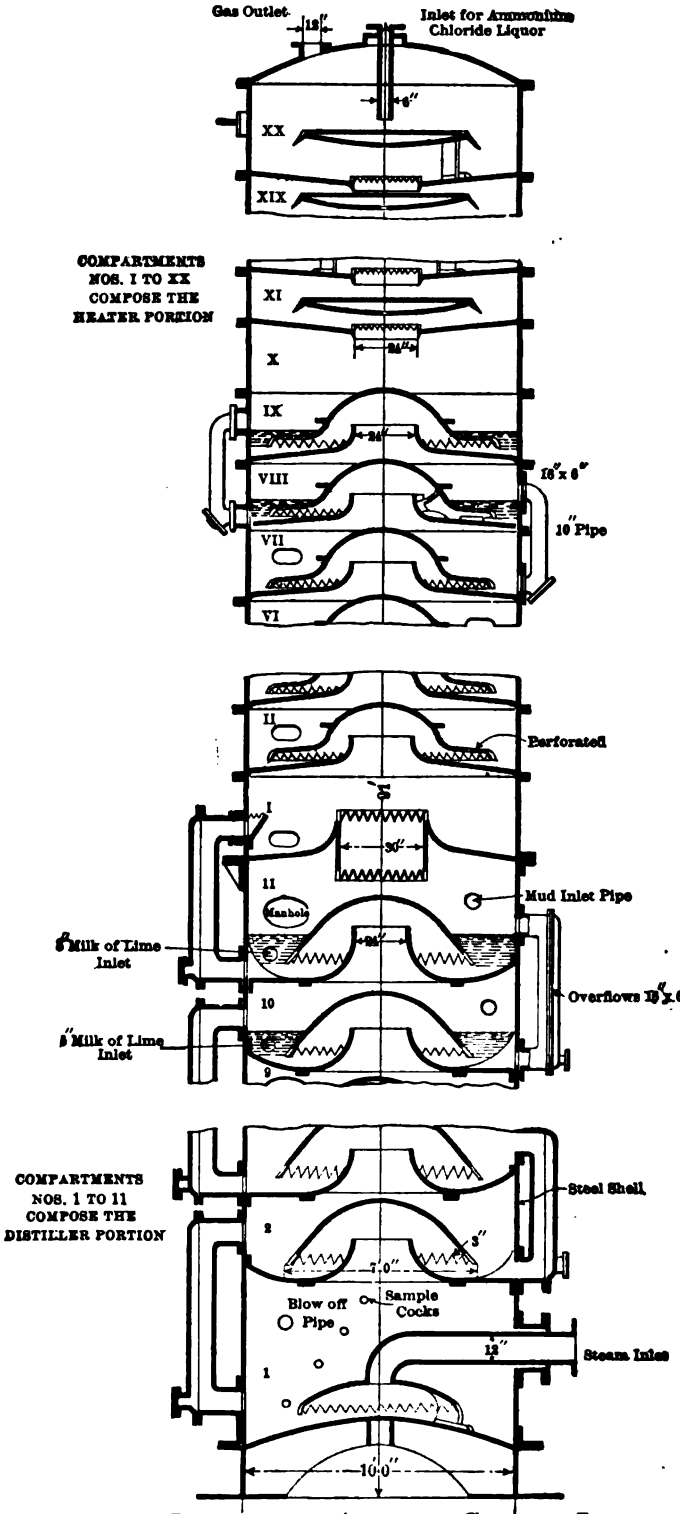


FIG. 1 DISTILLER FOR AMMONIUM CHLORIDE LIQUORS

The object in the upper compartments of the apparatus is to offer a minimum resistance to the ascending gas, and at the same time to split up the descending liquors as finely as possible. This is attained by having the denticulations of the corona plates finished off to a knife edge, the denticulations acting as distributors. The descending liquor then takes the form of a thin veil, which is broken through by the ascending gases. The lower portion of the heater is of the "bubble" type, which offers a greater resistance but brings the ascending gases into closer contact, at the same time the liquor is heated to a greater extent than could be done with a spray. It should be noted that the depth of the liquor or the seal over the perforations in the bubble plates should never exceed 3·5 in. If these dimensions are exceeded to any great extent, the resistance to the passage of hot ascending gases materially affects the economical working, and also increases the back pressure on the exhaust steam used in the distiller. A heater of this type is operated under a partial vacuum of from 2·5 in. to 7 in. of mercury.

The following table gives the results obtained in the practical working of the distiller. The determinations for free ammonia were made on samples of 20 c.c. each of solutions taken from the several compartments, while those for combined ammonia were made on samples of 200 c.c. each.

Distiller.					Heater.				
No. of Compartment.	Free Ammonia, Direct 20 c.c. Test.	Combined Ammonia by Distillation 200 c.c. sample	Carbon Dioxide.	Temperature. C.	No. of Compartment.	Free Ammonia, Direct 20 c.c. Test.	Combined Ammonia by Distillation 200 c.c. sample	Carbon Dioxide.	Temperature. C.
1.....	10·6	·24	5	102	1.....	36·1	86·2	1·2	89
2.....	11·6	·38	5·4	102	2.....	41·5	91·2	5·6	85
3.....	14·3	·48	5·4	101	3.....	61·0	114·6	17·6	83
4.....	10·2	·76	5·4	101	4.....	69·0	119·3	23·0	79
5.....	11·9	1·94	5·4	101	5.....	81·6	125·2	27·5	76
6.....	10·3	2·18	5·5	100	6.....	85·2	126·0	32·4	74
7.....	12·8	8·4	5·5	100	7.....	84·8	125·6	34·2	74
8.....	11·7	23·6	5·5	98	8.....	83·2	126·0	36·9	73
9.....	13·5	37·6	5·6	98					
10.....	20·6	157·5	5·7	96					
11.....	39·9	352·0	5·4	68					

The working of a distiller is continuous for four or five weeks, and consists in admitting the ammonium chloride liquors, or what is termed "filter liquors," to the top of the heater. During the descent the free ammonia is expelled while the combined ammonia is not driven off until the distiller portion of the apparatus is reached, where in contact with milk of lime it is liberated. Usually exhaust steam at from 15 to 20 lb. pressure is admitted at the bottom, as shown in the illustration. The waste lime is blown off from the bottom compartment.

In order to obtain the maximum efficiency for the distiller, the following factors of working must be carefully regulated:—

1. The temperature of the incoming liquor at the top, also that of the heater portion of the apparatus and of the outgoing gases.
2. The strength of the vacuum at the top of the heater.
3. The amount of lime and salt in the blow-off liquors.
4. The amount of free and combined ammonia in the incoming liquor and in the blow-off liquor (tested every 15 minutes).

The distiller described above will handle all the return ammonium chloride liquors for a plant producing 100 tons soda ash per day.

STONE.

THE leading varieties of stone produced in the United States in the order of their importance are limestone, granite, sandstone, marble and slate. Detailed information as to the important quarrying centers, character of their output, and the relative value of stones for different uses, will be found in THE MINERAL INDUSTRY, Vol. VIII. Slate is treated separately elsewhere in this volume.

The total value of the stone produced in the United States during 1901 amounted to $55,488,137, against $45,066,708 in 1900; neither of which totals includes the sandstone used in the manufacture of grindstones and whetstones, which is included under silica, and are also exclusive of the value of the production of slate, both of which may be found in detail elsewhere in this volume.

The value of the imports and exports of stone into the United States for the fiscal year ending June 30, 1901, was $1,276,602 and $774,614, respectively, the former inclusive and the latter exclusive of the respective values of slate.

Limestone.—The value of the total production during 1901 was $26,406,897, the value of that used for building being $5,219,310, including $404,163 for railroad bridges; for railroad ballast, $1,758,541; for macadam, $2,298,286; for concrete, $1,214,815; for riprap and rubble, $1,024,109; for the production of lime, $8,204,054; for blast furnace flux, $4,659,836, and for the limestone used in the manufacture of Portland cement, $570,882. The principal producers rank in the order of maximum production as: Pennsylvania, with a production valued at $5,081,387 for 1901; Illinois, $2,793,837; Indiana, $2,993,186; Ohio, $2,606,502; New York, $1,738,716; Missouri, $1,362,272; Wisconsin, $1,225,448.

Granite.—The total value of the granite produced during 1901 amounted to $15,976,971, which includes that used for concrete, $477,709; for road making, $2,008,966; and for railroad ballast, $516,768; for curbing and flagging, $670,703; riprap and rubble, $1,755,959; sold in the rough, $3,486,574, for paving blocks, $1,821,431; and for dressed building stone sold by the producers, $3,781,294. The principal States rank in the order of their maximum production as: Maine, $2,703,116; Massachusetts, $2,216,258; Vermont, $1,245,828; California, $1,134,675; South Carolina, $996,084, and New Hampshire, $935,494.

Sandstone.—The total value of the production during 1901 was $8,844,978, of which was used for building purposes, $4,875,973; for railroad ballast, $30,887; for road making, $130,503; for concrete, $123,957; for paving, $358,910; for riprap and rubble, $447,520; for curbing, $636,722; for flagstones, $1,026,499; for other purposes, including grind and whetstones, $1,214,007. The principal producing States rank in the order of production as: Ohio, with a total production valued at $2,576,723; Pennsylvania, $2,063,082; and New York, $1,331,327.

Marble.—The total value of the marble produced during 1901 was $4,965,699, of which that used for building purposes was $1,236,023; for ornamental work, $126,576; sold in the rough, $591,667; for interior work, $1,008,482, and for cemetery work, $1,948,892.

SULPHUR AND PYRITES.

THE production of sulphur in the United States during 1901 was 6,866 long tons, valued at $223,430, as compared with 4,630 long tons in 1900. The output by States in the order of importance was: Nevada, Idaho, Utah and Louisiana. The total quantity of sulphur produced in the United States has always been of insignificant proportions, as compared with the total consumption. More than 400,000 tons of sulphur, including the sulphur content of pyrites are consumed annually in the manufacture of sulphuric acid.

SULPHUR PRODUCTION, IMPORTS, AND CONSUMPTION IN THE UNITED STATES.

Year.	Production.			Imports.								Consumption. (a)	
	Sulphur.			Crude.		Flowers of Sulphur.		Refined.		Totals.			
	Long Tons.	Value.	Value per Ton	Long Tons.	Value.	Long Tons.	Value.	Long Tons.	Value	Long Tons.	Value.	Long Tons.	Value.
1897	1,690	$34,814	$20·60	138,846	$2,442,420	319·00	$7,950	148·00	$3,387	139,313	$2,453,757	140,809	$2,484,589
1898	2,726	59,754	21·92	159,790	3,081,974	507·00	14,548	163·00	4,391	160,460	3,100,913	161,772	3,128,845
1899	1,565	33,585	21·46	140,841	2,494,387	336·00	9,917	184·00	4,519	141,361	2,508,823	142,449	2,531,604
1900	4,630	102,091	22·05	166,457	2,918,610	628·00	17,437	243·00	6,279	167,328	2,942,326	171,418	3,080,922
1901	6,866	223,430	32·54	174,194	3,261,397	748·00	20,201	268·00	6,308	175,210	3,287,906	182,076	3,511,336

(a) In calculating the consumption of sulphur the exports were taken into consideration, although they do not appear in the above table, viz.: 1897, 194 long tons ($3,982); 1898, 1,414 long tons ($31,822); 1899, 477 long tons ($10,804); 1900, 540 long tons ($13,495); and 1901, *Nil.*

Market.—The average monthly price of seconds and thirds during 1900 and 1901 is given in the subjoined table:—

AVERAGE PRICE OF BRIMSTONE PER LONG TON IN NEW YORK.

Month.	1900.		1901.		Month.	1900.		1901.		Month.	1900.		1901.	
	Seconds.	Thirds.	Seconds.	Thirds.		Seconds.	Thirds.	Seconds.	Thirds.		Seconds.	Thirds.	Seconds.	Thirds.
January..	$21·79	$19·79	$22·67	$20·67	May.....	$21·50	$19·50	$26·69	$24·69	September	$23·73	$21·68	$22·75	$19·75
February	21·97	19·78	22·44	20·33	June.....	21·00	18·97	22·40	20·35	October...	23·00	21·25	24·69	21·31
March...	21·87	19·07	25·30	23·30	July.....	21·16	19·16	22·50	19·92	November.	22·50	19·94	26·25	22·50
April.....	21·37	19·31	22·06	20·06	August....	22·58	20·25	22·50	20·50	December.	22·18	20·05	24·25	21·25

Average for 1900: Seconds, $22·05; thirds, $19·89. Average for 1901: Seconds, $23·71; thirds, $21·23.

WORLD'S PRODUCTION OF SULPHUR. (a) (IN METRIC TONS.)

Year.	Austria (d)	France. (c)	Hungary	Germany	Greece.	Italy. (b)	Japan.	Russia.	Spain.	Sweden	United States.
1896.....	643	9,720	138	2,263	1,540	426,853	12,540	437	1,800	77	3,861
1897.....	530	10,723	112	2,317	358	496,658	12,013	574	*b* 3,500	*Nil.*	1,717
1898.....	496	9,818	93	1,954	135	502,351	10,389	1,018	3,100	50	2,770
1899.....	555	11,744	116	1 663	1,150	563,697	10,241	451	1,100	*Nil.*	1,590
1900.....	862	11,551	123	1,445	891	544,119	14,435	(e)	750	70	4,704

(a) From the official reports of the respective governments. The sulphur recovered as a by-product by the Chance-Claus process in the United Kingdom, amounting to about 31,000 long tons in 1898 is not included. (b) Crude. (c) Raw mineral; limestone impregnated with sulphur. (d) Crude rock. (e) Statistics not yet published.

Australasia.—During 1900 there were produced 1,692 long tons of sulphur in New Zealand, the product being consumed by the sulphuric acid makers of the State.

Chile.—The sulphur deposits at Taltal are being actively worked by a native company. It is reported that 60 men were employed during 1901. A company capitalized at $40,000 has been formed at Iquique to exploit the sulphur deposits in that vicinity, the product to be utilized at the nitrate works in Tarapaca and Atacama in the manufacture of blasting powder and in the extraction of iodine. The deposits are at an elevation of 3,500 or 4,000 m. and can only be worked during the summer months—from October to April. The location renders it very costly to transport the material to the railroad terminus, although the air-line distance is only 80 km.

Canada.—A large deposit of sulphur is reported to have been found on the Skeena river, B. C., and arrangements are being perfected to exploit the property with the view of shipping the product to Victoria and other Sound ports.

Greece.—Sulphur is found on the Island of Milos at Phyriplaka and Tsakistras as impregnations in weathered trachyte and at Phirlingos as irregular masses in porous sandstone (millstone). The earthy sulphur of Phyriplaka is used principally in grape culture, while the hard ores of Phirlingos are treated in distillation furnaces. At present there are five furnaces in operation all owned by La Société des Naraux Publiques et Communaux, and the annual production amounts to about 1,000 tons, which is consumed in the manufacture of sulphuric acid.

Italy.—The Trabonella Sulphur mines have recently been equipped with complete modern mining machinery. The old pillar method has been supplanted by the long wall system. A 600-H.P. Dawson gas engine motor driving six electric motors furnished light and power. Hoisting is accomplished by a 60-H.P. three-phase motor, giving a speed of 4·2 per second with an unbalanced load of 2·375 kg. A conical drum and a two-deck cage are used. Rich deposits of sulphur have been reported in the Comitini district, at the Cannarella mine near Castrogiovanni, and in the Agira district. It is reported that prospecting operations have been carried on satisfactorily.

SHIPMENTS OF SULPHUR FROM SICILY TO THE UNITED STATES. (IN LONG TONS.)

Port.	1895.		1896.		1897.		1898.		1899.		1900.		1901.	
	Seconds.	Thirds.	Seconds.	Thirds.	Seconds.	Thirds.	Seconds.	Thirds.	Seconds.	Thirds.	Seconds.	Thirds.	Seconds.	Thirds.
New York	35,888	19,975	50,557	17,796	57,174	13,300	49,614	22,475	56,746	26,650	70,446	24,307	72,104	19,631
Charleston	700	8,450	2,380	5,370	1,500	3,630	500	1,600	.....	.....	.....	.....	.....	.....
Philadelphia	1,200	7,150	500	5,500	199	5,210	1,200	5,400	2,740	8,000	1,600	5,100	2,300	9,595
Baltimore	1,100	8,620	3,650	10,500	3,798	10,088	2,350	12,015	3,800	8,600	6,800	5,400	7,550	2,900
Boston	2,350	2,600	4,600	700	7,220	1,000	4,500	1,550	600	1,000	1,500	2,500	3,497	3,300
Savannah	3,784	800	8,370	1,025	4,700	.....	1,980	.....	.....	.....	1,750	.....	.....	.....
Wilmington, N C.	.....	650	1,260	1,400	.....	1,550	500	1,200	.....	.....	.....	.....	.....	.....
New Orleans	1,700	.....	2,100	.....	3,340	.....	500	2,000	.....	800	.....	3,000	.....	1,400
Portland, Me.	1,300	.....	2,550	.....	4,343	.....	13,750	.....	18,915	.....	27,612	.....	21,990	.....
Other ports (a)	580	2,380	5,425	1,290	540	600	14,101	3,200	590	.....	12,490	.....	650	.....
Totals	48,602	50,625	81,342	43,581	82,814	35,323	88,995	49,440	83,391	45,050	122,198	40,307	108,091	36,726

(a) Norfolk, Mobile, San Francisco, Bangor, and Portland, Ore.

TOTAL EXPORTS OF SULPHUR FROM SICILY, 1893-1900. (*a*) (IN LONG TONS.)

Country.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.
Austria	10,169	11,494	12,170	13,799	15,993	15,796	18,519	21,594	18,842
Belgium	4,358	5,644	6,410	7,527	9,258	8,402	7,481	9,721	7,471
France	89,736	56,932	60,696	76,739	84,895	88,657	96,043	103,647	74,394
Germany	16,259	16,437	15,472	15,680	19,721	27,048	25,923	28,702	23,448
Greece and Turkey	13,840	16,870	16,195	18,556	13,866	24,908	18,056	19,647	21,702
Holland	2,957	2,865	3,335	3,834	3,599	5,646	6,408	18,595	10,848
Italy	54,486	49,895	49,349	54,009	73,052	62,652	87,230	101,073	74,516
Portugal	14,545	8,670	14,562	12,001	7,054	8,257	12,269	10,937	11,395
Spain	3,499	3,445	3,753	5,910	4,039	3,233	7,757	6,187	2,979
Sweden and Norway	*b*6,579	*b*7,887	*b*5,730	*b*14,540	*b*11,226	*b*12,331	*b*12,476	*b*22,681	24,486
Russia	19,730	17,977	17,962	18,752	17,532	12,285	19,211	22,090	15,110
United Kingdom	27,453	22,165	24,043	21,913	24,520	26,983	25,088	23,973	22,464
United States	83,901	105,773	99,227	124,923	118,137	138,493	128,441	162,505	144,817
Other countries	1,680	3,376	7,732	8,562	7,651	12,791	13,569	6,810	9,887
Totals	349,192	328,930	347,636	396,745	410,538	447,324	479,081	558,162	462,299
Stock in Sicily at end of year	210,665	198,513	203,756	222,999	240,367	248,023	277,098	221,204	302,410

(*a*) From report of A. S. Malcomson, New York. (*b*) Includes exports to Denmark.

The Anglo-Sicilian Sulphur Co., with an authorized capitalization of £1,035,000, of which £607,200 has been issued, reports for the fiscal year ending July 31, 1901, a net profit of £106,644, after placing £8,500 to the reserve fund. Dividends to the extent of £34,335 were paid, and £36,403 was credited to the general reserve fund, which is now £119,245. This, with the capital guarantee fund, provides a reserve of £171,620, exclusive of £36,529 which has been set aside for depreciation of stocks of sulphur. The company renewed the contracts with the Sicilian sulphur producers for 5 years from July 31, 1902.

Japan.—The production of sulphur in Japan during 1900 amounted to 14,435 tons, valued at £31,000. The output was derived mainly from the provinces of Hokkaido, Rikuzen, Asumi and Shenaro. The imports of Japanese sulphur into the United States during 1901 amounted to 10,705 long tons, valued at $206,899.

Russia.—Sulphur deposits have been reported near Damba and Shük, on the road to Askahbad (Kara-Kum), as well as in the vicinity of Kukurtinsk, between the railroad stations of Balla Ishem and Mulla Kara. During the last few years some several thousand tons of sulphur were obtained from the Kara-Kum district. A Belgian syndicate is about to exploit these deposits on a large scale.

Venezuela.—The German Venezuelan Sulphur Co., with a capital of 2,000,000 marks ($476,000), is actively at work setting up the aërial cable by which the sulphur will be carried from the mine, near Carupano, to the port, a distance of about 18 km. The landing wharf is finished and the managers await only the termination of the wire-rope railroad to begin loading on a large scale.

PYRITES.

The production of pyrites in the United States during 1901 was 234,835 long tons ($1,024,449), as compared with 201,307 long tons ($684,478) in 1900. In spite of this large increase the demands were far in excess of all records. It now seems out of the question materially to increase the tonnage mined in the Eastern States, and as there have been no new developments of properties nor any increased developments of mines in Massachusetts, Virginia and Georgia,

the condition exists that foreign pyrites must be consumed in a greater proportion than ever before. This means that the prices will be steadied to a point where it will become possible to open up new sources of pyrites to meet the greater demands for manufacture of fertilizers, the refining of oils and general chemical use.

The most available supply of sulphur at present and most generally distributed over the country where consumption of acids is greatest is the zinciferous sulphur ores of Arkansas, Missouri, Kentucky, Kansas and other States. Millions of tons of these ores are obtainable and can be brought to common centers for extraction of their sulphur content, yet up to the present time only three plants have been established for this purpose, *viz.*: at Peru and Peoria, Ill., and at Argentine, Kan. By the use of specially constructed mechanical furnaces it is possible to save from 25 to 28% of the sulphur in these ores, bringing the cinders down to about 2% S, and a subsequent roasting in a Falding or Chase furnace will fit the material for extraction of the zinc by cheap methods. The coming year promises the installation of other roasting plants, so that doubtless the tonnage of sulphur from pyrites will be largely augmented by the utilization of the sulphur from zinc sulphides, thus keeping the balance between domestic and foreign sulphur ores to its present ratio.

The industrial activity of the United States is responsible for the enormously increased demand for sulphuric acid, and it is not difficult to prognosticate that should prices remain normal as at present, within a few years the demand for sulphuric acid of inland consumers will be supplied in a large part from domestic zinc and other sulphide ores.

The largest consumers of sulphuric acid,—the Virginia-Carolina Chemical Co., the American Agricultural Co. and the Standard Oil Co.,—now purchase ores, from which the acid is manufactured. Fully 90% of all the acid manufactured in the United States is required for the different uses of these corporations.

The purchase in the United States of all domestic and foreign pyrites and other ores used for the sulphur content is practically in the hands of four trade combinations, and as the total purchases amount to approximately 500,000 tons annually, stocks of foreign ores can be accumulated at the seaboard and shipped inland in quantities to secure lowest freight rates; the importation of foreign ores is favored and but little incentive is left to develop domestic mines of uncertain character.

PRODUCTION, IMPORTS AND CONSUMPTION OF PYRITES IN THE UNITED STATES. (*a*)
(IN TONS OF 2,240 LB.)

Year.	Production.		Imports.			Consumption.	
1897.....	133,368	$404,699	259,546	47%	$847,419	392,914	$1,252,118
1898.....	191,160	589,329	171,879	47%	544,165	363,039	1,133,494
1899.....	178,408	583,323	310,008	47%	1,074,855	488,416	1,658,178
1900.....	201,317	684,478	329,449	47%	1,089,093	530,766	1,774,171
1901.....	234,825	1,024,449	403,706	47%	1,415,149	638,531	2,439,598

(*a*) These statistics do not include the auriferous pyrites used for the manufacture of sulphuric acid in Colorado.

Market.—The heavy consumption of pyrites by makers of sulphuric acid for

the fertilizer trade favored an increased domestic production and larger imports than in 1900. Prices were firm as the important consumers make season contracts in advance. In Virginia producers quoted f. o. b. Mineral City $4·90 per long ton for lump ore, and $4·20 for fines (basis 42% S). Massachusetts miners quoted f. o. b. Charlemont $5@$5·50 for lump ore, and $4·75@$5 for fines. A prominent importer at New York contracted for the output of some Spanish mines and subsequently made good-sized contracts with consumers in the United States. The ocean freight from Huelva, the leading shipping port in Spain, fluctuated between $1·92 and $2·34 per ton to Atlantic ports. Spanish pyrites sold here at 12@14c. per unit of sulphur. The imports of Spanish and other pyrites into the United States in 1901 totaled 403,706 long tons, as against 329,449 tons in 1900.

Georgia.—The Durgey property, near Villa Rica, owned by the Virginia-Carolina Chemical Co., has been brought to the producing stage and promises to be a steady shipper of high-grade pyrites. There are several prospects which have been developed more or less, one of them in Harrelson County,—the Gamble mine,—and one of them in Carroll County, from which several thousand tons have been raised to the surface, but no shipments of consequence have been made.

Massachusetts—The Davis mine was the only producer and has kept up its record for steady shipments and uniform products. All this ore is marketed near at home, and in this respect is and has been an exceedingly favorable mine proposition.

New York.—(By W. H. Adams.)—The Stella mine, at De Kalb Junction, was a producer for only a few months during the year. The deposits were opened only to supply the actual demands up to the time when the mine was closed. The shipments were about equal in tonnage, the lump ore averaging about 35% and the concentrates averaging about 48% S. The machinery is not up to modern requirements, and this property, a very promising one, deserves development and working on a large scale. Every ton to be produced from this mine can be marketed within a short distance, and there is a constantly growing trade connected with sulphite pulp mills which could be handled from this location.

Virginia.—(By W. H. Adams.)—The Arminius Chemical Co., the Pyrites Mining & Chemical Co., and the Sulphur Mineral & Railroad Co. operated the mines in Louisa County during 1901 and, with the Detrick mines, near Quantico, Prince William County, produced about 145,000 tons.

Domestic Consumption of Sulphur and Pyrites.—The use of iron pyrite as a raw material in place of sulphur for the manufacture of sulphuric acid continues to increase steadily. By far the greater part of the sulphur consumed in the United States is used in the manufacture of paper stock by the sulphite process. The wood pulp is digested under pressure with sulphurous acid or the acid sulphite of calcium and magnesium, which, reacting upon the lignin and other incrusting material of the fiber, transforms them into soluble products which are subsequently removed in the liquor.

The increased use of pyrites for acid making has been due very largely to the development of the sulphite wood-pulp industry for the manufacture of paper in which sulphur is used. There is but one sulphite mill in the United

States using pyrite in place of sulphur in the treatment of wood pulp, although in Europe a considerable quantity of pyrite is utilized for this purpose. Another important factor has been the increased production of phosphate rock from Florida and Tennessee and the domestic manufacture of superphosphates. For these purposes a chemically pure sulphuric acid is not essential, and that made from pyrite serves the purpose equally as well as that made from sulphur.

CONSUMPTION OF SULPHUR IN THE UNITED STATES. (IN TONS OF 2,240 LB.)

	1898.	1899.	1900.	1901.
Domestic production of sulphur	2,726	1,865	4,630	6,966
Imports of brimstone	159,790	140,841	166,457	175,210
Total	162,516	142,406	171,087	183,076
Exports of brimstone	1,414	477	540	*Nil.*
Consumption	161,102	141,929	170,547	182,076
Sulphur contents at 99%	157,880	139,090	167,136	178,434
Domestic production of pyrites	191,160	178,408	201,317	234,925
Imports of pyrites	171,879	310,008	329,449	403,706
Sulphur in domestic pyrites at 44%	84,110	78,500	88,579	103,323
Sulphur in foreign pyrites at 47%	80,779	145,704	154,841	189,742
Total sulphur consumed in pyrites	164,889	224,204	243,420	293,065
Total sulphur consumed in brimstone	157,880	139,090	167,136	178,434
Grand total	322,769	363,294	410,556	471,499

In the above table the imports and exports are for crude sulphur or brimstone only; the figures of consumption, therefore, differ slightly from those given in the preceding table on page 598.

WORLD'S PRODUCTION OF PYRITES. (*a*) (IN METRIC TONS.)

Year.	Belgium.	Bosnia.	Canada.	France.	Germany.	Hungary.	Italy.	Newfoundland.
1896	2,560	2,000	30,586	282,064	129,168	52,697	45,728	27,712
1897	1,898	3,670	35,299	303,448	133,302	44,454	58,330	33,316
1898	147	240	29,228	310,972	136,849	58,079	67,191	33,100
1899	263	430	25,117	318,882	144,623	79,519	76,538	31,570
1900	400	1,700	36,316	305,073	169,447	87,000	71,616	(*b*) 33,000

Year.	Norway.	Portugal.	Russia.	Spain. (*d*)	Sweden.	United Kingdom.	United States.	Totals.
1896	60,507	(*c*)	11,550	464,882	1,009	10,178	117,782	1,440,072
1897	94,484	210,265	19,380	217,545	517	10,753	128,468	1,295,046
1898	89,763	248,218	24,570	260,016	886	12,302	194,219	1,465,086
1899	95,636	275,658	23,251	319,285	150	12,426	181,263	1,584,511
1900	(*b*) 95,000	345,330	(*b*) 25,000	356,018	179	12,484	204,538	1,743,011

(*a*) From the official reports of the respective governments except the figures for Spain in 1897, which are taken from C. Le Neve Foster's report. (*b*) Estimated. (*c*) Not reported. Under Portugal is included only the output of pyrites carrying less than one per cent. of copper. Considerable amounts of the richer sulphides are also used in sulphuric acid manufacture. In completing the totals the output in 1896 is estimated at 200,000 metric tons. (*d*) Does not include the production of copper-iron pyrites, from which the copper is extracted in Spain.

Sulphuric Acid.—The average prices of chamber and concentrated sulphuric acids in 1900 and 1901 are given in the subjoined table, which has been compiled from *The Engineering and Mining Journal*:—

Month.	Conc. Acid. 66° B. per 100 Lb.		Chamber Acid. 50° B. per Ton.		Month.	Conc. Acid. 66° B. per 100 Lb.		Chamber Acid. 50° B. per Ton.	
	1900.	1901.	1900.	1901.		1900.	1901.	1900.	1901.
January	$1·22½	$1·20	$16·16⅔	$14·00	July	$1·20	$1·20	$14·00	$14·00
February	1·21½	1·20	15·12½	14·00	August	1·20	1·28	14·00	14·00
March	1·20	1·20	14·00	14·00	September	1·20	1·12½	14·00	14·00
April	1·20	1·20	14·00	14·00	October	1·20	1·10	14·00	14·00
May	1·20	1·20	14·00	14·00	November	1·20	1·20	16·00	14·00
June	1·20	1·20	14·00	14·00	December	1·20	1·20	16·00	14·00
					Average	1·20⅜	1·17⅛	14·27⅛	14·33⅓

Progress in the Sulphuric Acid Industry during 1901.

By F. J. Falding.

The year 1901 has been characterized not so much by any startling novelty in the manufacture of sulphuric acid as by earnest work looking to the improvement of the technique, both of the old chamber process and the contact process.

In Germany, exceedingly important papers have been published, the one a masterly treatment of the manufacture of sulphuric acid by the contact process, by Rudolf Kneitsch,[1] of the staff of the Badische Anilin und Soda Fabrik, which is given in full detail later in this section; another, by Fr. Luty and H. H. Niedenfuhr,[2] being a discussion of the comparative costs of production of sulphuric acid by the contact process and modern lead chamber processes; also one by Dr. Theo. Meyer, on "The Reform of the Chamber Processes."[3]

In France, L. Pierron has supplemented his valuable report to the International Congress of Applied Science, of Paris, fully quoted in The Mineral Industry, Vol. IX., by a special paper relating to the manufacture of sulphuric acid by the contact process.[4]

These interesting papers are so remarkable for careful thought and so frank in their disclosures of the results of costly and laborious experiment and experience as to make the year remarkable if nothing else had been done.

The Contact Process.—Dr. Kneitsch, by means of an examination of the history of the contact process, shows how failure followed failure until the quantitative conversion of sulphurous into sulphuric acid was regarded as absolutely hopeless; how finally "the surprising discovery was made that there are substances which can even in exceedingly minute quantities diminish the catalytic action of the platinum to an extraordinary extent." He further states that "the harmful action of arsenic alone, for example, was found to be so great that even in quantities amounting to only from 1 to 2% of the platinum contained in the contact mass it sufficed to render it entirely inactive." Even with this certain knowledge of the cause of failure, success still seemed to be hopeless, as at that time the entire removal of the arsenical fumes from the burner gas was considered technically impossible. Finally after years of "enormous expenditure of time, trouble, money and patience, experiment following experiment, the solution of the problem was found," so that now it is "quite possible to rid the burner gas completely of all its impurities by subjecting it, after suitable treatment and cooling to a systematic and continued intimate contact with water or sulphuric acid. The manner in which the intimate contact with purifying liquids is obtained is a matter of indifference so far as the final result is concerned. For example, extensive washing and moist filtration alone or in combination are found to be equally effective."

Dr. Kneitsch states here that after the complete purification of the burner gas seemed to have been arrived at a gradual deterioration of the contact mass still

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[1] *Berichte der Deutschen Chemischen Gesellschaft*, No. 17, Dec. 28, 1901.

[2] *Zeitschrift fuer Angewandte Chemie*, No. 11, March 18, 1902.

[3] Zur Reform des Bleikammer processes, *Zeitschrift fuer Angewandte Chemie*, No. 50, 1901.

[4] "La Fabrication de l'Acide Sulfurique" (Hist.: des procedés par contact), *Revue de Chimie Industrielle* (2), Vol. XIII., No. 148, April, 1902.

took place. This was at last found to be due to the action of the acid formed in the cast-iron cooling pipes by which small quantities of arsine (As_2H) were formed. After the cooling pipes were protected from the action of the acid "the activity of the contact mass remained unchanged." Dr. Kneitsch also states that there is not the least difficulty in obtaining a quantitative conversion of SO_2 into SO_3 without pressure of any kind; a fact of great importance in practice.

With regard to the absorption of the SO_3 Dr. Kneitsch states the remarkable fact that only sulphuric acid of from 97 to 98% H_2SO_4 will absorb SO_3 instantly and completely. His researches into the action upon iron of sulphuric acid of various strengths are technically invaluable—to use his own words: "on these observations we have based a method for the production of sulphuric acid almost absolutely free from iron." Probably, however, the most interesting part of the result of experiments recorded is that relating to the temperature at which the contact reaction takes place. On heating the contact oven containing platinized asbestos the rapidity of the reaction increases, so that at from 380 to 400°C. nearly all the SO_2 is found to be converted into SO_3. From 400 to 430°C. the reaction remains nearly uniformly quantitative, a conversion of 98 to 99% being maintained. From this point the curve falls, but not as rapidly as it rose before. At 700 to 750°C. only about 60% of the SO_2 is converted, and at 900 to 1,000°C. no reaction can any longer be detected. After describing various experiments, Dr. Kneitsch states: "As the important result of these experiments we have found, then, a line of stable equilibriums which divides the whole range of temperatures into two divisions. Temperatures below 200°C. and above 900 to 1,000°C. may be regarded as resulting in no technical reaction; between 200 and 450°C. the formative reaction preponderates, while above this the decomposition of the sulphuric anhydride rapidly becomes prominent. From these facts important technical conclusions can be drawn; for, even if the boundary line has been determined for one particular technical gas mixture, the various modifications occurring in practice will scarcely have a very great influence in the position of this stable equilibrium. Further, it is evident that this temperature boundary line must be, theoretically and practically, independent of the kind of contact material, from which it follows that only such contact substances will be capable of bringing about an approximately quantitative reaction *in a single operation* as have their highest activity at the temperature of the zone of formation, that is, under about 450°C. All contact substances that develop their maximum power only beyond this temperature will never be able to bring about a quantitative yield, however long they remained in contact with the gases. At present there is only one contact substance which fulfils these conditions, namely, platinum; nor can this be replaced by any of the other metals of the platinum group, even with approximately good results."

Dr. Kneitsch adds the following statement of the yearly growth of the manufacture of sulphuric acid in terms of sulphuric anhydride at the works of the Badische Anilin und Soda Fabrik: 1888, 18,500 tons of SO_3; 1894, 39,000 tons; 1899, 89,600 tons; 1900, 116,000 tons. Dr. Kneitsch also gives some hitherto unpublished and very precise and complete descriptions of the physical and chemical properties of different strengths of sulphuric acid.

In connection with Dr. Kneitsch's statement regarding the reaction temperature and the line of stable equilibrium of SO_3 and his conclusion that platinum contact mass is the only contact substance "capable of bringing about an approximately quantitative reaction in a single operation," it is interesting to read Mons. Pierron's conclusions on the subject of the technical production of sulphuric anhydride.

"There is a difference of opinion amongst technical men on the subject of the 'modus operandi' of obtaining the most economical results. The object being to convert the greatest possible quantity of SO_2 into sulphuric acid. There are two methods which can be used:—

"First, to regulate the temperature of the contact oven in such a way that only a very small quantity of SO_2 will escape unconverted.

"Second, to follow the ordinary contact oven (from which a considerable quantity of SO_2 is allowed to escape unconverted) by one or more contact ovens in series in which the SO_2 escaping from the first oven is converted into SO_3. These secondary ovens can either contain the same contact substance or substances having a different contact action."

This last plan, *i.e.*, the combination of several ovens in series has recently been recognized as technically the most practical, as is proved by the fact that certain concerns such as the Verein Chemische Fabrik Mannheim, The Badische Anilin und Soda Fabrik, Meister Lucius und Bruning after having in their early patents treated the operation as complete in a single catalytic reaction, have in their recent patents described the use of a series of apparatus as being advantageous.

The four contact plants erected early in 1901 under the Grillo-Schroeder patent,[5] after meeting with difficulties natural to new processes and novel and untried conditions, are stated to be working regularly and producing a satisfactory yield of acid. Other works are about to be established. Of these four plants one is using the waste gas from roasting zinc blende; two are using arsenical Spanish fines, and one highly arsenical gold and silver concentrates. It is not necessary to say that more difficult raw materials to handle could not well have been selected, and the ultimate success of these plants therefore is all the more satisfactory.

A steady improvement has been made especially in Germany in the various parts of the chamber plant, especially in the accuracy of details tending to secure a complete functioning of the various apparatus. This is notably the case in the packing of the Gay-Lussac, Glover and intermediate towers and surface condensers, as also in the pumping and acid distributing arrangements and all details of construction and operation which tend to reduce the size of the apparatus and to secure a maximum production at a minimum of cost.

The Meyer-Tangential chamber system, mentioned last year[6] as being in operation at Harburg and Rensberg, in Germany, is now in operation in the United States at the works of Griffith & Boyd, in Baltimore, Md.

I regard this system not only as being rational but also as being the first and only distinct advance in construction of the lead chamber proper. As erected

[5] THE MINERAL INDUSTRY, Vol. IX., p. 617. [6] *Ibid.*, p. 618.

in Baltimore, with the exception of some cooling pipes inserted into the roof of the first chamber, these chambers are perfectly plain and without any adventitious aid such as fans, surface condensers, etc. The system consists of a set of lump burners, Glover tower—three cylindrical chambers 30 ft. diameter by 34 ft. high with tangential gas connections at the upper periphery and bottom central outlet, with a small preliminary cooling tower, and final Gay-Lussac tower. During the summer weather these chambers are working at the rate of not less than 10 and not more than 11 cu. ft. of space to 1 lb. of sulphur burned; the yield is excellent, and while at this particular plant the consumption of nitrate of soda is too high, both the results obtained in this respect in Germany and the rationale of the process would tend to show that such high consumption of nitrate of soda is unnecessary and is due either to some defect in construction or operation. When it is considered that to approach or equal these results either the skilled management necessary for "marche intensive" or costly apparatus such as fans, surface condensers or Lunge intermediate towers must be made use of, the economy of construction becomes evident with a consequent economy of land, buildings, repairs, amortization and interest. On the other hand if this system were used in connection with the above appurtenances it is difficult to surmise just what the output of such a plant would become.

The most recent proposition for the manufacture of sulphuric acid is that of C. B. Jacobs,[7] assignor to the Ampere Electro-Chemical Co., of Jersey City, N. J.

Mr. C. P. Townsend[8] states that "Faraday and a host of subsequent experimenters have investigated the electrolytic oxidation of sulphur dioxide in aqueous solution, and have found that under normal conditions one-half the oxide undergoes oxidation to sulphuric acid at the anode, the remainder appearing as sulphur or hydrogen sulphide at the cathode. In 1895, however, Dr. Leonard Wacker succeeded in rendering the oxidation quantitative by the concurrent use or production of carriers of oxygen, such as the persulphates, or even the halogens. Mr. Charles B. Jacobs now finds that the same result may be accomplished by a judicious application of the principle that oxidation is facilitated by a concentrated solution and low current density at the anode. In Jacobs' apparatus the anode is a porous composition through which the gas is injected in a continuous stream into the cell; and the anode area is 33 times that of the cathode. In the apparatus used the vessel is provided with horizontal electrodes and an interposed diaphragm. The porous anode constitutes a partition near the base of the cell, and into the lower compartment so formed sulphur dioxide is injected through the pipe, passing through the previous anode and undergoing oxidation therein. An outlet is provided for withdrawal of the sulphuric acid when the hydrometer shall indicate that the desired density has been reached. A refrigerating jacket is provided in order that advantage may be taken of the increased solubility of sulphur dioxide at 0°C.

"Jacobs, like Wacker, finds that by continuously injecting sulphur dioxide, the sulphuric acid may be brought to standard concentration. The electrolytic efficiency is given as 54%, with a potential difference of two volts and a current density of 15 to 20 amperes per sq. ft. of anode surface."

[7] United States Patent No. 704,831, 1902.

[8] *Electrical World and Engineer.*

The following tables have been compiled and calculated by Mr. F. J. Falding from the tables of the United States Manufacturing Chemists' Association and other authorities.

TABLES FOR SULPHURIC ACID CALCULATIONS.

Bé. U. S.	Sp. Gr.	Weight of 1 Cu. Ft. in Lb. Av.	Per Cent. O. V.	Pounds O. V. in 1 Cu. Ft.	Per Cent. SO_3.	Per Cent. H_2SO_4.	Per Cent. 60°.	Pounds 60° in 1 Cu. Ft.	Per Cent. 50°.	Pounds. 50° in 1 Cu. Ft.
0	1·000	62·27	0·00	0·00	To reduce percentages of H_2SO_4 to terms of SO_3 multiply by 0·816326.	0·000	.....	.....	.....	.....
1	1·007	62·81	1·00	0·63		0·935	.....	.....	.....	.....
2	1·014	63·24	2·50	1·58		2·337	.....	.....	.....	.....
3	1·021	63·68	3·66	2·33		3·422	.....	.....	.....	.....
4	1·028	64·12	5·00	3·21		4·675	.....	.....	.....	.....
5	1·036	64·62	6·00	3·88		5·610	.....	.....	.....	.....
6	1·043	65·05	7 00	4·55		6·545	.....	.....	.....	.....
7	1·051	65·55	8·00	5·24		7·480	.....	.....	.....	.....
8	1.058	65·99	9·00	5·94		8·415	.....	.....	.....	.....
9	1·066	66·49	10·25	6·82		9·584	.....	.....	.....	.....
10	1·074	66·99	11.50	7·70		10·752	.....	.....	.....	.....
11	1·082	67·49	12·50	8·44		11·687	.....	.....	.....	.....
12	1·090	67·98	13·60	9·25		12·716	.....	.....	.....	.....
13	1·098	68·48	14·70	10·07		13·744	.....	.....	.....	.....
14	1·107	69·04	16·00	11·05		14·960	.....	.....	.....	.....
15	1·115	69·54	17·00	11·82		15·895	.....	.....	.....	.....
16	1·124	70·10	18·25	12·79		17·064	.....	.....	.....	.....
17	1·133	70·67	19·60	13·85		18·326	.....	.....	.....	.....
18	1·442	71·23	21·30	14·96		19·635	.....	.....	.....	.....
19	1·151	71·79	22 00	15·79		20·570	.....	.....	.....	.....
20	1·160	72·35	23·25	16·82		21·739	.....	.....	.....	.....
21	1·169	72·91	24·50	17·86		22·907	.....	.....	.....	.....
22	1·179	73·58	26·00	19·12		24·310	.....	.....	.....	.....
23	1·188	74·10	27·25	20·19		25·479	.....	.....	.....	.....
24	1·198	74·72	28·50	21·30		26·647	.....	.....	.....	.....
25	1·208	75·34	30·00	22·60		28·050	.....	.....	.....	.....
26	1·218	75·97	31·25	23·74		29·219	.....	.....	.....	.....
27	1·229	76·65	32·75	25·10		30·621	.....	.....	.....	.....
28	1·239	77·28	34·00	26·28		31·790	.....	.....	.....	.....
29	1·250	77·96	35·50	27·68		33·192	.....	.....	.....	.....
30	1·261	78·65	37·00	29·10		34·595	.....	.....	.....	.....
31	1·272	79·32	38·37	30·44		35·876	.....	.....	.....	.....
32	1·283	80·02	39·75	31·81		37 166	.....	.....	.....	.....
33	1·295	80·77	41·25	33·32		38·569	.....	.....	.....	.....
34	1·306	81·46	42·62	34·72		39·850	.....	.....	.....	.....
35	1·318	82·20	44·00	36·17		41·140	.....	.....	.....	.....
36	1·330	82·95	45·50	37·74		42·542	.....	.....	.....	.....
37	1·342	83·70	47·00	39·34		43·945	.....	.....	.....	.....
38	1·355	84·51	48·50	40·99		45·347	.....	.....	.....	.....
39	1·368	85·32	50·00	42·66		46·750	.....	.....	.....	.....
40	1·381	86·13	51·50	44·36	39·308	48·152	62·05	53·44	77·44	66·70
41	1·394	86·94	53 00	46·08	40·458	49·555	63·85	55·51	79·70	69 29
42	1·408	87·82	54·50	47·86	41·597	50·957	65·66	57·66	81·95	71·97
43	1·421	88·63	56·00	49·63	42·743	52·360	67·47	59·80	84·21	74·64
44	1·436	89·56	57·50	51·50	43·887	53·762	69·28	62·05	86·47	77·44
45	1·450	90·44	59·00	53·36	45·033	55·165	71·08	64·28	88·72	80·24
46	1·465	91·37	60·50	55·28	46·177	56·567	72·89	66·60	90·98	83·18
47	1·479	92·25	62·00	57·20	47·323	57·970	74·70	68·91	93·23	86·00
48	1·495	93·24	63·50	59·21	48·467	59·372	76·50	71·33	95·49	89·08
49	1·510	94·18	65·00	61·22	49·612	60·775	78·31	73·75	97·74	92·05
50	1·526	95·18	66·50	63·29	50·757	62·177	80·12	76·26	100·00	95·18
51	1·542	96·17	68·00	65·40	51·902	63 580	81·93	78·79	102·26	98·34
52	1·559	97·23	69·70	67·77	53·199	65·169	83·98	81·65	104·81	101·91
53	1·576	98·30	71·30	70·09	54·420	66·665	85·90	84·44	107·22	105·40
54	1·593	99·36	73·00	72·53	55·718	68·225	87·95	87·39	109·77	109·07
55	1·611	100·48	74·60	74·96	56·940	69 751	89·88	90·31	112·18	112·72
56	1·629	101·60	76·20	77·42	58·161	71·247	91·81	93·28	114·59	116·42
57	1·648	102·79	77 87	80·40	59·435	72·808	93·82	96·44	117·10	120·37
58	1·666	103·91	79·50	82·61	60·679	74·332	95·78	99·52	119·55	124·22
59	1·686	105·16	81·30	85·50	62·053	76·015	97·95	103·00	122·26	128·57
60	1·706	106·40	83·00	88·31	63·351	77·605	100·00	106·40	124·81	132·80
61	1·726	107·65	85·00	91·50	64·877	79·475	102·41	110·24	127·82	137·60
62	1·747	108·96	87·00	94·80	66·404	81·345	104·82	414·21	130·83	142·55
63	1·768	110·27	89·00	98·14	67·931	83·215	107·23	118·24	133·83	147·57
64	1·790	111·64	91·62	102·29	69·930	85·665	110·39	123·24	137·77	153·81
64·5	1·801	112·33	83·12	104·60	71·075	87·067*	.....	.....	.....	.....
64·75	1·807	112·70	94·00	105·94	71·747	87·890	.....	.....	.....	.....
65	1·812	113·01	94·70	107·02	72·281	88·544	114·10	128·94	142·41	160·94
65·25	1·818	113·39	95·66	108·47	73·014	89·442	.....	.....	.....	.....
65·5	1·824	113·76	96·86	110·12	73·884	90·508	.....	.....	.....	.....
65·75	1·830	114·14	98·33	112·28	75·052	91·939	.....	.....	.....	.....
66	1·835	114·45	100·00	114·45	76·3265	93·500	120·48	137·89	150·88	172·11

TABLES FOR SULPHURIC ACID CALCULATIONS.—*Continued.*

Per Cent. SO_3 Found by Titration.	Per Cent. H_2SO_4.	Per Cent. SO_3.
70·7840	94	.....
77·5509	95	.....
78·3678	96	.....
79·1836	97	.....
79·9999	98	.....
80·8163	99	.....
Fuming Acids.		
81·6320	100	0
81·8163	99	1
82·0000	98	2
82·1836	97	3
82·3674	96	4
82·5510	95	5
82·7346	94	6
82·9183	93	7
83·1020	92	8
83·2857	91	9
83·4693	90	10
83·6530	89	11
83·8367	88	12
84·0204	87	13
84·2040	86	14
84·3877	85	15
84·5714	84	16
84·7551	83	17
84·9387	82	18
85·1224	81	19
85·3061	80	20
85·4897	79	21
85·6734	78	22
85·8571	77	23
86·0408	76	24
86·2244	75	25
86·4081	74	26
86·5918	73	27
86·7755	72	28
86·9591	71	29
87·1428	70	30
87·3265	69	31
87·5102	68	32
87·6938	67	33
87·8775	66	34
88·0612	65	35
88·2448	64	36
88·4285	63	37
88·6122	62	38
88·7959	61	39
88·9795	60	40
89·1632	59	41
89·3469	58	42
89·5306	57	43
89·7142	56	44
89·8979	55	45
90·0816	54	46
90·2653	53	47
90·4489	52	48
90·6326	51	49
90·8163	50	50
91·0000	49	51
91·1836	48	52
91·3673	47	53
91·5510	46	54
91·7346	45	55
91·9183	44	56
92·1020	43	57
92·2857	42	58
92·4693	41	59
92·6530	40	60
92·8367	39	61
93·0204	38	62
93·2040	37	63
93·3877	36	64
93·5714	35	65
93·7551	34	66
93·9387	33	67
94·1224	32	68
94·3061	31	69
94·4897	30	70
94·6734	29	71
94·8571	28	72
95·0408	27	73
95·2244	26	74
95·4081	25	75
95·5918	24	76
95·7755	23	77
95·9591	22	78
96·1428	21	79
96·3265	20	80
96·5102	19	81
96·6938	18	82
96·8775	17	83
97·0612	16	84
97·2448	15	85
97·4285	14	86
97·6122	13	87
97·7959	12	88
97·9795	11	89
98·1632	10	90
98·3469	9	91
98·5306	8	92
98·7142	7	93
98·8979	6	94
99·0816	5	95
99·2653	4	96
99·4489	3	97
99·6326	2	98
99·8163	1	99
100·0000	0	100

YIELDS IN POUNDS OR KILOGRAMS OF SULPHURIC ACID SOLUTION PER 100 LB. OR KG. OF AVAILABLE SULPHUR OR SULPHUR OXIDES ACTUALLY CONTAINED IN BURNER GAS.

Percentum of Theoretical.	Sulphuric Anhydride SO_3=100%.	SO_3 = 60% / H_2SO_4=40% / SO_3=32·65%	SO_3 = 40% / H_2SO_4=60% / SO_3=38·96%	SO_3 = 20% / H_2SO_4=80% / SO_3=86·31%	Monohydrate H_2SO_4=100% / SO_3=81·6326%	Distilled H_2SO_4=98·5% / SO_3=80·41%	Extra Concentrated H_2SO_4=97% / SO_3=79·18%	Oil of Vitriol 66° U. S. Bé H_2SO_4=93·5% / SO_3=76·33%	Glover Tower Acid 62° U. S. Bé. H_2SO_4=81·35% / SO_3=66·41%	Pan Acid 60° U. S. Bé H_2SO_4=77·0% / SO_3=62·85%	Chamber Acid 50° U. S. Bé. H_2SO_4=62·18% / SO_3=50·76%
	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
100	250·00	269·83	280·96	293·05	306·25	310·91	315·78	327·53	376·45	394·63	492·51
99	247·50	267·13	278·15	290·12	303·19	307·80	312·56	324·26	372·69	390·70	487·59
98	245·00	264·43	275·34	287·19	300·13	304·69	309·41	320·99	368·93	386·76	482·67
97	242·50	261·74	272·53	284·26	297·06	301·58	306·25	317·72	365·17	382·81	477·74
96	240·00	259·04	269·72	281·33	294·00	298·47	303·09	314·44	361·40	378·86	472·82
95	237·50	256·34	266·91	278·40	290·94	295·36	299·98	311·16	357·64	374·92	467·89

GERSTER'S FORMULA FOR MIXING A STRONG SOLUTION OF SO_3 WITH A WEAK SOLUTION OF SO_3 TO PRODUCE AN INTERMEDIATE SOLUTION OF SO_3 OF ANY DESIRED STRENGTH.

$$X = 100\frac{b-a}{a-c}$$

When X = quantity of weak solution required to mix with 100 parts of the strong solution.

a = total SO_3 in 100 parts of the solution desired; b = total SO_3 in 100 parts of the strong solution; c = total SO_3 in 100 parts of weak solution.

Approximate Calculation of Volume of Burner Gas at 32°F. and 29·92 in. (0°C. and 760 mm.).—1 cu. ft. of SO_2 weighs 0·1787 pound av. (1 liter weighs 2·86336 grams), and contains 0·1787÷2=0·08935 lb. S. Therefore, 1 lb.

sulphur burned in 24 hours produces 11·191942 cu. ft. of SO_2, or 0·0077722 cu. ft. per minute: Therefore, neglecting SO_3 formed

$$\left(\frac{0{\cdot}77722 \times \text{actual sulphur burned in 24 hours}}{\text{average per cent. of } SO_2 \text{ in burner gas produced}}\right) =$$

cubic feet of burner gas per minute, or for 10,000 lb. of sulphur burned in 24 hours (7,772·2÷7·5)=1,036·3 cu. ft. per minute of burner gas containing 7·5% SO_2.

To Correct for Higher Temperatures at Normal Pressure.—Co-efficient of expansion of air = 0·003667=$\frac{1}{273}$ and that of ordinary burner gas may be taken as slightly in excess of that of air (say $\frac{1}{270}$ to $\frac{1}{273}$) at 0°C. and 760 mm. The volume at t°C. is $V + \frac{V \times t°C.}{271}$ or for 10,000 lb. S in 24 hours 7·5% SO_2 burner gas at 760 mm. and 100°C. (V as above = 1,036·3 cu. ft.)

$$1{,}036{\cdot}3 + \frac{1{,}036{\cdot}3 \times 100}{271} = 1{,}418{\cdot}7 \text{ cu. ft.}$$

HYDRATES OF SO_3.

SO_3 = 100·00% SO_3.	$SO_3 + 2H_2O$ = 68·97% SO_3.
$4SO_3 + H_2O$ = 94·68% SO_3.	$SO_3 + 3H_2O$ = 59·70% SO_3.
$2SO_3 + H_2O$ = 89·89% SO_3.	$SO_3 + 5H_2O$ = 47·07% SO_3.
$4SO_3 + 3H_2O$ = 85·56% SO_3.	$SO_3 + 151H_2O$ = 2·86% SO_3.
$SO_3 + H_2O$ = 81·63% SO_3.	

SULPHURIC ACID AND ITS MANUFACTURE BY THE CONTACT PROCESS.[1]

BY R. KNEITSCH.

IT is hardly necessary to call special attention to the fact that the manufacture of sulphuric acid is a matter of the greatest industrial interest; for it is rightfully considered as the basis not only of inorganic chemical industry, but also in later years of the manufacture of organic dyes. In addition it is used in manifold industries. This is the case particularly in the manufacture of alizarin dyes, and most recently in the manufacture of synthetic indigo.

When a complete revolution takes place in an industry of such importance, a presentation of these discoveries and proved principles which have made this revolution possible may be of interest. Briefly summarized the chief results as obtained by the Badische Anilin & Soda Fabrik are as follows: The chemical reaction representing the production of sulphuric acid is an exceedingly simple one, and apparently chemistry plays only a subordinate part in it. This simple process is a very interesting and important example of a gas reaction which takes place only at high temperatures. The reaction between sulphur dioxide and oxygen, although it is exothermic, takes place only very slowly and for this reason it has always been the endeavor of industrial chemists to accelerate it by the use of catalytic substances. The old chamber process itself is based upon the use of a catalytically acting substance, as nitric acid or the lower oxides of nitrogen.

There are also a number of solid contact substances which, however, act only at a higher temperature; but because they are solids, there is no loss of contact

[1] A lecture delivered before the German Chemical Society, Oct. 19, 1901. Translated by O. H. Ruhoff.

material. Above all they exercise their catalytic action in the complete absence of water, producing not dilute H_2SO_4, as in the chamber process, but sulphuric anhydride itself.

I. Historical.

The historical development of the contact process may be divided into four periods, the first of which is opened in 1831 by the discovery of the catalytic action of platinum in the sulphuric acid process. The second period may be dated from the discovery by Mohler and Mahla in 1852 of the catalytic action of a number of substances and the clearing up of the mechanism of the reaction in the case of several catalysors. The third period was brought to life by Winkler, and is characterized by the use of certain particular mixtures of gases for the production of sulphuric oxide, which according to views held at that time, were particularly compounded for the quantitative production of anhydride. In the fourth period, finally, burner gases were again made use of.

The practical results to which these efforts tended, differed from each other in that the earlier ones, as also those of the fourth period, had as their object the supplanting of its chamber process by means of catalytic substances, while the workers of the third period, after the great number of failures of their predecessors, confined themselves to the production of fuming sulphuric acid which was at that time still very high in price.

The discoverer of the catalytic action of platinum in general was Humphry Davy,[2] who announced in January, 1817, that heated platinum wire, when brought into a mixture of oxygen or air with hydrogen carbon monoxide, ethylene, or cyanogen, etc., became heated to redness and that then the mixture burns sometimes slowly, often, however, rapidly. Edmund Davy discovered in 1820 that finely divided platinum obtained by precipitating a solution of platinum with hydrogen sulphide, treating the precipitate with nitric acid, evaporating the solution and boiling the residue with alcohol, glowed in the air, the alcohol being consumed. Dobereiner found in 1822 that the residue obtained by heating ammonium platino-chloride when moistened with alcohol shows the same phenomenon in the air, and in 1823 that in the presence of air finely divided platinum ignites a current of hydrogen directed against it. Upon this fact Dobereiner based his famous lighting machine in 1824. The honor of having applied this catalytic action to the production of sulphur trioxide belongs, as before mentioned, to the acetic acid manufacturer, Peregrine Phillips, Jr., of Bristol, who took out an English patent[3] on his invention in the year 1831.

Soon after, in the year 1832, two eminent German scientists, Dobereiner and Magnus[4] confirmed the discovery of Phillips. After Phillips' discovery had remained idle for 17 years, the problem of the manufacture of sulphuric acid

[2] Kopp, *Geschichte der Chemie*, Vol. 3-4, p. 226.

[3] English Patent No. 6,096, 1831.

[4] Mangus confirms, in *Poggendorf's Annalen*, 24, p. 610, Phillippe's assertion that sulphurous acid and oxygen, or air (the latter only more slowly), heated with platinum or, better, spongy platinum, may be condensed to sulphuric acid, and Dobereiner says in the same journal at the end of a discussion on making of oxygen ethers by means of platinum black: "I have succeeded in condensing a mixture of two volumes of sulphurous acid by means of hygroscopically moist platinum black." Even though Dobereiner does not mention Phillips' name it may be assumed with certainty that he, as well as Magnus, knew of Phillips' discovery and the work of both of them was only intended to prove Phillips' assertions.

without lead chambers was claimed as solved by the Belgian chemist Schneider,[5] who, as he stated, believed he had found in a specially prepared pumice stone a catalytic substance of high activity. This alleged discovery, though given to the world with much ado,[6] never gave evidence of any success. The sanguine hopes of that period are evidenced by a portion of a letter which Clement Desorme wrote to Schneider in the year 1835, years after Phillips' discovery. It reads literally as follows: "I am convinced that in at most 10 years it will be possible to manufacture sulphuric acid on a large scale, out of its constituents, without lead chambers, nitric acid, or salts; do not lose courage, and direct your efforts toward this important end."

From this it is evident that the great object was plainly marked out even in the year 1835.

Richard Lovering was just as over-sanguine as Schneider in the description of his discovery, for he too claimed to have discovered a process for the production of sulphuric acid without the use of lead chambers. Again pumice stone was said to be exerting its wonderful power, and prepared by being boiled in concentrated sulphuric acid, then brought into ammoniacal water, dried, and thereupon treated with about 1% of MnO_2. Then it was to be again treated in a retort to 600°F. and allowed to cool without access of air. Here, for the first time, is mentioned a different contact substance, which, like platinum, occurs in different degrees of oxidation, *viz.:* manganese compounds. But here too, a complete failure seems to have destroyed great hopes, as in Schneider's case. According to Dengler, Lamun's patent was even a plagiarism on Schneider's work.

The English patent of 1846, by Jullian,[7] deserves particular mention, because here the use of platinized asbestos is mentioned for the first time. Jullian intended to use this catalytic substance, which later became so important, among other things for the production of sulphuric acid. As forerunners of the second period there appears the beforementioned work of Lamun as also the experiments of M. C. Blondeau[8] (1849). The latter passed a mixture of sulphur dioxide steam and air through a glowing porcelain tube filled with clayey sand containing iron, and obtained sulphuric acid.

[5] Schneider exhibited before a Belgian committee a model apparatus in which he made sulphuric acid for a whole day by burning sulphur. The committee came to the following characteristic conclusions, based on Schneider's claims and experiments:

"(1) That according to Schneider's method, sulphuric acid can be made without the use of nitric acid or nitrates. (2) That the yield of acid approaches the maximum hitherto reached in sulphuric acid plants. (3) That the committee is not acquainted with the method by which the property of combining sulphurous acid with the oxygen of the air is imparted to pumice, so that it must confine itself to mentioning the inventor's claim that his manner of preparing the pumice stone involves but a slight expense." What the secret manner of preparing the pumice stone was, therefore, was not made public, but it is very probable that Schneider wanted to profit by Phillips' discovery without mentioning it, but grossly deceived himself regarding the discovery. In the year 1848, he says, for instance, regarding his alleged discovery: "Of late the most eminent chemists, Gay-Lussac, Clement, Desormes, Dumas, Payen, Bussy, Chevallier, Peligot and others have been working on this discovery. But there is still lacking an apparatus enabling us to do without the lead chambers in the manufacture of this acid. I believe that I have solved this problem in its practical as well as its scientific aspect."

[6] Schneider closes his experiments in the year 1848 with the words: "I believe that I have neglected nothing in achieving a result which is an important advance in the manufacture of sulphuric acid. My chief purpose was to construct an apparatus which can take the place of the lead chambers and the platinum stills. I have been completely successful in this."

[7] English Patent No. 11,425, 1846.

[8] *Comptes Rendus*, 29, 405, 1849. Blondeau's work was based upon an observation of Boussignault's, who had noticed that sulphuric acid occurred in rivers in whose vicinity the gases of burning iron sulphide deposits had been converted into sulphuric acid by the heat of the combustion under the influence of clayey sand and slate.

Then came Mohler and Mahla's discovery in 1852 that copper, iron and chromium oxides gave evidence of catalytic properties similar to spongy platinum and sheet platinum with a mixture of sulphurous acid and oxygen, and that mixtures of copper oxide and chrome oxide were particularly active. These investigators, too, gave even then a correct explanation of catalytic action, for they found that copper oxide and ferric oxide, heated without blast excess of air are reduced to cuprous acid and ferrous acid, with formation of sulphuric acid. As soon as the reduction is complete the formation of sulphuric acid stops. Chromic acid, however, remains entirely unchanged when heated with sulphuric acid without presence of air, and no trace of sulphuric acid is found. Metallic copper in the spongy form, or mercury, brought into a mixture of two volumes of sulphurous acid and one volume of oxygen, have no action on each other. If, however, heat is applied, then, when copper is used there is first formed copper oxide and only then sulphuric acid. The two investigators further pointed out that the presence of moisture in the gases is not necessary for the formation of sulphuric acid. These important observations are the foundation of the later investigations of Lunge in the catalytic action of burnt pyrites, as also the very recently worked out process for the production of sulphuric acid by means of burnt pyrites, of the Verein Chemischer Fabriken.[9]

In the year 1852 Plattner and Reich likewise worked with the use of heated quartz, but unsuccessfully. It is very interesting to note that even at this time Robbe proposed ferric oxide or powdered pyrites cinders as contact substances. Pirie recommended, besides heated quartz, pumice stone saturated with a solution of platinum as a substitute for metallic platinum. Thornthwaite[10] (1854) comes in for mention at this place. Among other things he again took up Jullian's idea of using platinized asbestos, manganese dioxide, first mentioned as contact mass by Lamung, and further had Mohler and Mahla's observations protected for himself by an English patent. Into this period there belongs further the work of Alfred Truemann.[11] He impregnated clay with platinic-chloride, and formed from this a red heat metallic platinum.[12]

Hundt,[13] in 1854, allowed burner gases to pass through a canal which was heated up by the heat of the gases themselves and which was lined with pebbles so as to convert as large a portion as possible of the sulphurous acid into sulphuric acid, and then worked up the burner gases further.[14]

In the year 1855 Schmersahl and Bank[15] prepared sulphuric acid by passing sulphur dioxide, air and steam over heated contact substances, absorbing the sulphuric acid thus formed, and continuing this process until all the sulphur dioxide had been converted into sulphuric acid.

Henry Deacon[16] took out patents in the year 1871 aside from those on his

[9] German Patents Nos. 107,995 and 108,446. [10] English Patent No. 188, 1854. [11] English Patent No. 992, 1854.

[12] Trueman's patent treats of the use of platinum or ferric oxide with pumice stone or other porous materials, for the manufacture of sulphuric acid from burner gases. He describes also the use of porous substances which have been saturated with the sulphates of iron, copper, chromium and manganese, and then heated to redness, in order to form the active oxides by driving off the sulphuric acid.

[13] English Patent, Feb. 16, 1854.

[14] Hundt believed also that the burner gases could be converted into sulphuric acid in sprayed towers alone, without the use of chambers.

[15] English Patent No. 188, 1855. [16] English Patents Nos. 753 and 1,682, 1871.

celebrated chlorine process, in which the production of sulphuric acid by means of his contact substances, especially copper sulphate, is described.[17]

This closes the second period of the historical development, which, like the first, is characterized by having made its purpose the attainment of the—I should like to say "great"—end, of supplanting the chamber process by the contact process. These efforts, however, gave no evidence of practical success, and it was not even possible to produce fuming sulphuric acid cheaply enough to compete with Stark's product obtained by the distillation of slate containing iron sulphate. The turning point in the manufacture of sulphuric acid was made by the work of Clemens Winkler who, from experimental investigations on the formation of sulphuric acid from sulphur dioxide and oxygen, came to the conclusion that only a stochiometrical mixture of 2 volumes of SO_2 and 1 of O was suitable for a conversion of these into SO_3 as complete as possible, and that all other gases, even oxygen, exercised a harmful influence on the progress of the reaction. This stochiometrical mixture Winkler produced in a very simple manner by decomposing ordinary hydrated sulphuric acid by means of heat, into water, sulphurous acid and oxygen, and removing the water. In this way he obtained by the subsequent concentration of the gases, sulphuric anhydride or fuming sulphuric acid. This work, which became celebrated, was published in *Dingler's Journal* in 1875. The assertion based by Winkler upon his experiments read as follows: "According to these experiments, of 100 parts by weight of sulphurous acid used there are converted into sulphuric acid under various circumstances: (*a*) of a mixture of pure sulphurous acid and pure oxygen, 73·3 parts by weight; (*b*) of a mixture of pure sulphurous acid and air, 47·4 parts by weight; (*c*) of a gas containing 4 to 5% by volume of sulphurous acid obtained by burning sulphur in a current of air, 11·5 parts by weight.

"It is evident from this that the action of platinized asbestos and doubtless of other contact substances is decreased in proportion as the dilution of the sulphurous acid by other indifferent gases becomes greater. Of course oxygen and sulphurous acid themselves remain inactive and so act as diluents in so far as they are not present together in the stochiometrical proportions necessary for the formation of sulphuric acid, and one or the other is present in excess. In the abovementioned experiments this condition was unavoidable, and it may be for this reason that even when pure oxygen was used, only about 75% of the sulphurous acid was converted into sulphuric acid.

"It is a well-known fact that ordinary English sulphuric acid is broken up at a bright red heat into sulphurous acid, oxygen and water vapor. Of these three decomposition products the water vapor can be completely condensed, and there then remains a gaseous mixture of oxygen and sulphurous acid in exactly the proportions necessary for making sulphur trioxide. In this way it was possible to prevent the harmful admixture of any indifferent gases, and it was now only necessary to recombine the dried decomposition products, by contact action. There would thus be formed sulphuric acid, and the whole process

[17] Deacon noticed the fact that the reaction takes place better when air or oxygen are used in excess, but mentions that in that case larger quantities of gas have to be heated and moved.

amounts then to an indirect transformation of hydrated sulphuric acid to anhydrous acid."

This view of the most suitable conditions for the contact process for sulphuric acid appeared to be very reasonable, at that time, and well suited to explain all the failures of Phillips' reaction when applied to the utilization of the burner gases. Winkler's work caused a great stir at that time and influenced further work on the contact process for a long time after that. At about the same time the same process was discovered also in Messel's[18] works and protected by patents. Winkler published a new method for making contact substances, *viz.*: by utilizing the reducing action of formalin.[19]

This daring advance of Winkler's at once called into life the technical synthetic production of fuming sulphuric acid which up to that time had been attempted in vain, for a number of manufacturers,—among the first of whom was the Badische Anilin & Soda Fabrik,—took up the new process, with his work as a basis and Stark's monopoly in Bohemia was broken. For this reason the whole industrial world has occasion to be thankful to Winkler for the stimulus given by him to technical work. Further work in this field was now ruled by Winkler's influence, for example, Hänish & Schröder's[20] patent, taken out 11 years later; they replaced pure oxygen by air but still used pure sulphur dioxide and as a correction for the diluting influence of the nitrogen had the reaction take place under pressure, in order, as the patent says, to bring the molecules of the gases closer together. This process, too, was tried in the Badische Anilin & Soda Fabrik. Messel[21] and Lunge (Ellice Clark[22]) proposed a method of obtaining the stochiometrical mixture and excluding the nitrogen of the air, *viz.*: by roasting pyrites with oxygen. None of these processes, however, was capable of competing with the chamber process, and therefore had to be confined to making the fuming sulphuric acid.

Still further attempts to solve this problem have not been lacking but practically nothing has become public about such work. Winkler himself published nothing about his work in this direction, nor any results he may have obtained that conflicted with his publication, so that it was only a year ago that it became known by Lunge, and Winkler's significant lecture in Hanover on the development of sulphuric acid manufacture, that at his instigation however burner gases had been used at the Muldener furnace and two-thirds and at most three-quarters of the sulphur dioxide obtained in them had been converted into sulphuric acid.

From a patent of Rath's, too,[23] which deals with the utilization of burner gases, evenly mixed with fire gas, nothing of importance can be gathered. The patent gives chiefly a description of how the gases are to be freed from moisture and unconsumed organic admixtures, while no particulars are given about the contact process itself other than that the gases are to be led through contact cylinders heated to redness. Nothing was ever heard of any practical success of the process.

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[18] English Patent, Sept. 18, 1875.
[19] German Patent No. 4,566, 1878.
[20] German Patent No. 42,215, 1886.
[21] English Patent No. 1,828, 1878.
[22] English Patent No. 3,166, 1888.
[23] German Patent No. 22,118.

II. Purification.

The problem of transforming burner gases completely into sulphuric acid by the contact action remained for solution, but considering everything that was known about it at that time, it was regarded as hopeless. When I approached the problem in the works of the Badische Anilin & Soda Fabrik, it was chiefly theoretical considerations which made the possibility of accomplishing the great purpose seem not altogether hopeless, as it is well known the gases leaving the sulphuric acid chambers still contain 6% of oxygen. If no change was made in roasting, there would have to be this same excess of oxygen in every contact process working with burner gases, and it was not comprehensible why in spite of such an excess of oxygen the reaction should not take place quantitatively. This question was investigated with purposely highly diluted gases made by mixing pure sulphur dioxide gas with air, and it could be proved that under certain conditions a complete cessation of the reaction occurred only very close to a quantitative conversion. Strange to say it was found that the greatest dilution with air had practically no influence on the transformation into sulphur trioxide of the sulphur dioxide gas that was present. It even seemed that the conversion was improved in proportion with the dilution; the relation between oxygen and sulphur dioxide gas in the mixture being changed in favor of the oxygen.

It proved from this fact that the views held up to this time that diluting gases acted unfavorably on the progress of the contact process required a critical investigation. Experiments were now tried with conditions as they occur in practice, that is, burner gases. For this purpose burner gas was led directly to the laboratory from the pyrites burners by means of a long lead pipe, the latter acting as a long dust canal, and freeing the gas as much as possible from flue-dust and other mechanical impurities. Besides this the gas was drawn through several wash bottles containing sulphuric acid before it entered the tube containing the contact mass. The result was gratifying in no slight degree, for almost as favorable results were obtained in this way as before with an artificial gas mixture.

A decrease in the contact action could not be noticed though the action was continued for several days with the same contact mass, so that it seems quite justifiable to hope that in this very practical manner sulphuric acid could be produced almost quantitatively directly from burner gases. The experiments were therefore tried on a large scale. It was now seen very soon that the activity of the contact mass did not remain constant after having been used for some time and finally ceased entirely. There was no change in this state of affairs when the burner gases were not only cooled in long canals and repeatedly washed with sulphuric acid—exactly as in the laboratory experiments—but were also passed through dry coke and asbestos filters, so that they could be regarded as clean as was technically possible. The experiments on a large scale had to be considered failures; then, though confidence in success had been badly shaken by these unexpected failures, further laboratory experiments were made in order to determine the cause of the slow but none the less sure deterioration of the contact mass.

In these experiments the surprising discovery was made that there are substances which even in exceedingly minute quantities, can diminish the catalytic action of the platinum to an extraordinary extent. Among the first of these substances belongs arsenic, quicksilver, and phosphorus,[24] while antimony, bismuth lead, iron, zinc, and other substances which would have to be taken into consideration in roasting, are harmful only in so far as they naturally cover and clog the contact mass when carried over into it. The harmful action of arsenic alone, for example, was found to be so great that even quantities amounting to 1 to 2% of the platinum contained in the contact mass sufficed to make it entirely inactive. By these investigations it had, then, been irrefutably determined that there are bodies which are actually capable of exerting a specific, one might almost say, poisonous action on the contact process. The question was therefore, whether, in spite of the method of purification described above, there were still bodies of the character contained in the burner gases used. It could be determined, in fact, that the white mist of sulphuric acid in them which could not be precipitated, contained chiefly arsenic.

Though the reason for our failures appeared to have been revealed by the recognition of this fact, still no remedy for the evil was known. For at that time the complete deposition of the white mist, the so-called "Hüttenrauches" (arsenical fume), was considered technically impossible according to the most eminent experts.[25] The prospects for ultimate success after such long and laborious efforts now became very doubtful. But now that the harmful influence had been discovered, the new problem to be solved was taken up with renewed energy; this was, to free the burner gas of all impurities completely so that finally there would remain only a mixture of absolutely pure gases, *viz.:* sulphurous acid, oxygen and nitrogen.

With an enormous expenditure of time, trouble, money and patience, experiment was followed by experiment in order to accomplish this great purpose, and it may be said without exaggeration that it was one of the most difficult problems in the progress of the industry to show the well-known revolution in the sulphuric acid industry. It is impossible in this short time to go into the details of the experiments, which required several years of the severest effort after the process was being tried on a large scale, before a positively certain purification of the burner gases could be regarded as having been accomplished. The difficulty of this problem lay chiefly in the fact that there had to be carried on a wearing struggle with, one might say, an invisible foe, and that every misstep avenged itself by influencing for some time the output of the whole work. The result[26] of this is that it has become quite possible to rid the burner gas

[24] A subsequent and more searching investigation of the harmful action of phosphorus showed that this was only the result of the arsenic it contained.

[25] Extract from *Schnabel's Huettenkunde*, 1890, p. 500: "Contrivances for catching flue-dust and for condensing metallic vapors in furnace gases (Huettenrauch), are based upon cooling, filtration, washing, contact with surfaces, diminution of velocity and change of direction of the current of gas. Electricity of high tension has also been used as an experiment. Neither the first-mentioned methods, separately nor a combination of them in the most various ways have until now been found sufficient for completely freeing "Huettenrauche" from the substances mentioned. A large field for inventive genius is still open in this field."

[26] German Patent No. 113,983, July 22, 1898.

completely of all its impurities, by subjecting it, after suitable treatment and cooling, to a systematically continued intimate contact with water or sulphuric acid. This has to be continued until an optical and chemical examination demonstrates the complete absence of all harmful admixtures. The manner in which the intimate contact with purifying liquids is obtained is a matter of indifference so far as the final result is concerned. For example, extensive washing and moist filtration, alone or in combination, were found to be equally effective. I should like to mention in particular only a few of the difficulties which came up in the purification of the gases on a large scale. To obtain good results it had been found best to cool the gases slowly. For it is an exceedingly remarkable and a not yet sufficiently explained phenomenon, that the sulphuric acid mist of the burner gas is deposited with much greater difficulty when the latter is cooled rapidly than when cooled slowly.

For this purpose there was necessary a long iron flue which could be cooled by the air. Nothing was known at that time of any harmful influence that such a flue might exert on the contact process, for the sulphuric acid contained in burner gases when dry pyrites are used, has a strength of over 90% H_2SO_4, so that if the iron were attacked it was to be expected that it would be only with evolution of sulphur dioxide, which in itself could not be harmful to the process. In spite of the fact that the gases were now completely free from mechanical impurities, so that the optical test which at that time was still regarded as sufficient, did not give evidence of even the slightest trace of any impurity, the gases were even filtered through masses of moist filtering material, so arranged as apparently to secure perfect purification, yet it was seen that the contact mass lost its activity very slowly (only after weeks and months) but with unfailing certainty. After long and difficult lapses and after the presence of arsenic, in spite of its apparently complete removal by the above described process of purification had been confirmed with certainty by examination of the inactive platinized asbestos, it was conjectured that the cause for all these disturbances might be traced to the reaction products, the sulphuric acid condensing in small quantities in the iron cooling flues, and it became more and more certain that arsenical gas, probably arsine (AsH_3) must have been formed here. Such changes were made as were necessary to prevent the condensing sulphuric acid from coming in contact with the iron cooling flue, and from this time the activity of the contact furnaces remained unchanged; some hydrogen must have been evolved by the action of concentrated sulphuric acid on iron, contrary to the views held up to that time, for it is only thus that arsine (AsH_3) can be formed.

This ended probably the most obstinate struggle that was fought in the introduction of the new sulphuric acid process, although this struggle was not the last. In carrying out the process on a still larger scale, new disturbances occurred in the purification of the gases, whose causes were almost as mysterious and impossible to foresee as the one above mentioned. When the pyrites burners were run to their full capacity, there resulted misty formations which mocked all efforts to precipitate them. The explanation for their existence was finally found after a long search in very slight quantities of mist composed of uncon-

sumed sulphur. This mist, like quickly cooled sulphuric acid mist, could be deposited only with the greatest difficulty. But how could sulphur act harmfully, when it would only burn to sulphurous acid in the contact apparatus? The explanation is that the sulphur mist also was found to contain arsenic, and therefore had to be removed.

A radical means for the purpose was finally found in the thorough mixing of the still hot burner gas, so as to insure the combustion of even the last traces of sulphur. This mixing is most suitably accomplished by means of a jet of steam, the use of which is attended with the important advantages that the strong sulphuric acid present in the gas is diluted, and does not condense in the preliminary iron coolers, therefore not attacking them with formation of arsine nor, as a result of its low concentration does it destroy the main coolers of lead, when it condenses. Besides this the steam prevents the formation of hard crusts of flue-dust in the canals and coolers, which otherwise easily causes them to become obstructed.

The problem of regenerating a contact mass which has become inactive is dealt with by two patents[27] of the "Actien Gesellschaft für Zink Industrie vorm: Grillo & Schroeder. Their mode of procedure is based on the assumption that it is impossible in practice to remove all impurities from the gases. One of their patents therefore proposes the use of soluble salts as a carrier for the platinum, so that the ineffective platinum may be regenerated, while the other consists of removing the inactive contact mass by means of chlorine.

III. Regenerating Cooling.

We come now to another principle of great importance in the contact process, *viz.:* the rational removal of the harmful excess of the heat of reaction. As is known, the chemical process taking place in the contact process, is exothermic and may be expressed as follows:—

$$SO_2+O=SO_3+22{,}600 \text{ cal.}$$

But little attention had hitherto been paid, in the technology of fuming sulphuric acid, to this great evolution of heat. It is true that in Lunge's *Handbuch der Soda Industrie* reference is made to a process which is said to consist of heating a mixture of pure sulphur dioxide and air only to the temperature necessary for the contact process and then to allow it to pass into a contact apparatus which is not to be further heated, but only protected as much as possible from cooling, and which similarly to a Deacon chlorine apparatus was filled with platinized spheres of clay. But in this apparatus there was used a highly contracted mixture of gas, containing about 25% SO_2 by volume, and no conclusions could be drawn from it with regard to conditions that would exist when burner gases from 3 to 4 times more dilute were used. On the contrary it was generally considered necessary in the use of ordinary gas mixtures, not only to protect the contact vessels against radiation but to heat them directly to redness.

Accordingly, the contact apparatus first constructed by us was provided with

[27] German Patents Nos. 115,838 and 102,244.

heating arrangements suitable for this purpose. In order to economize in costly platinized asbestos, vertical contact tubes of not too great width were used, since it was found that in such tubes the platinum asbestos could be uniformly distributed with greater certainty than in other horizontal tubes or vessels. Thus the contact furnace consisted of a series of narrow iron tubes, the lower halves of which were filled with contact mass, as is shown in the accompanying drawing taken from our patent (Fig. 1A). When this furnace was set into operation at the customary low red heat, the exceedingly surprising observation was made that not only the yields rose, but that also the volume of the current of gas could also be very comfortably increased if in place of the hot fire gases from the lower heating arrangement, cold air was introduced between the pipes and thereby the

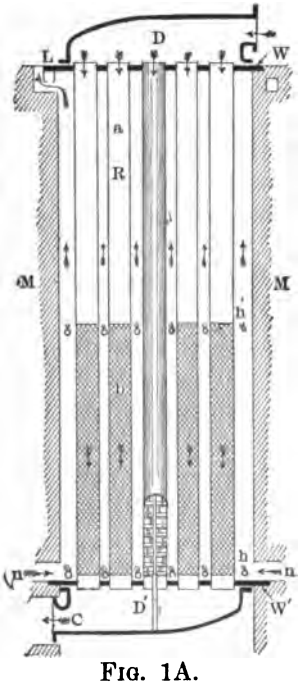


FIG. 1A.

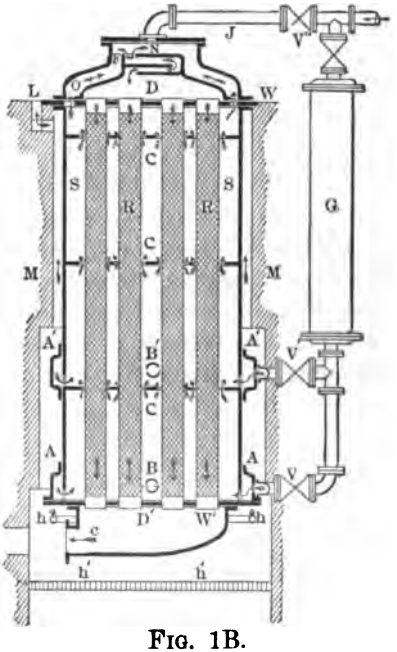


FIG. 1B.

CONTACT APPARATUS OF THE BADISCHE ANILIN UND SODA FABRIK.

temperature of the furnace materially lowered. By this experiment the road was opened to a rational operation of the contact furnaces,[28] just the opposite of the former mode of procedure. The furnaces had to be cooled in an adjustable manner if there was to be a maximum conversion and capacity. Such a furnace was operated by first heating up the cold furnace with both heaters, h and h'. As soon as the furnace had been set in operation the lower heater h was extinguished and cold air led by the contact mass, so that on the one hand the mass was cooled, and on the other hand the mass affected by the rising heated current of air and heating of the incoming cold gases which had to be completed by the heater h'. As could be seen with the eye, only the upper layers of the contact mass now became heated to dull redness, and by the passage of the

[28] German Patent No. 113,932, June 3, 1898.

gases there was maintained a degree of heat best suited for the completion of the reaction. This simple mode of operation and type of furnace which I have described stood the test of years; further the temperature may be observed continuously even without pyrometers, by the direct observation of the series of tubes.

Further investigation showed that the quantity of heat which could be extracted without injury from the contact process was so great that it seemed possible to use the burner gases themselves as cooling gases and thus utilize the excess heat of reaction directly for preheating the cold burner gases. In this way originated the various modifications of our apparatus described in our German patent, one of which, for example, is shown in Fig. 1B.

The manner of utilizing the heat of reaction is described by a patent of the "Höchster Farbwerke,"[29] according to which the heat of the gases after they have left the contact vessel is made use of. If we consider the effects of the cooling of the gases more closely we find that by it chiefly four important results are accomplished: (1) An overheating of the apparatus is prevented and such a temperature maintained as assures securing the theoretically possible highest yields, that is, 96 to 98%. (2) The iron apparatus is protected against premature destruction by the lower temperature at which the reaction takes place. (3) The contact mass is kept from becoming overheated and retains an undiminished degree of activity for years, and (4) The absolute capacity of the contact mass and thus also of the apparatus, is quite considerably increased, because fresh quantities of gas can continually be passed through the contact mass without overheating it, and because the contact mass itself is brought to a temperature most favorable for the greatest capacity. Should the furnace become overheated it is now no longer necessary, as formerly, to diminish the quantity of the gas to be converted, but its cooling action is regulated by varying its quantity, or its temperature as it enters the cooling spaces, or by a suitable change of the point at which it enters.

Another encouraging characteristic of the new process is that the reaction takes place without the application of pressure. You will remember that according to the views formerly held, the influence of inert gases was to hinder the reaction so that it was believed that this harmful influence had to be counteracted by using highly compressed gases. But, either there is no such influence or it amounts to practically nothing. There is not the least difficulty in obtaining under the right conditions, even without additional pressure, a quantitative conversion of SO_2 to SO_3. This fact is of great importance in practice; for when it comes to competing with the chamber process, all large expenditures must be avoided. To carry on the process rationally it is, on the other hand, necessary that the gas should be compelled to pass through the contact mass itself and come into the most intimate contact with it. But with such loose material as platinized asbestos, this necessitated a firm, close packing, which again resulted in a great resistance to the passage of the gases.

The object to be accomplished therefore was to reduce the resistance in the contact mass to a minimum without however leaving any other passageway open for the gas except through the mass, and still not to make it impossible

[29] German Patent No. 105,876.

to cool the contact tube. This was accomplished by a very simple apparatus[30] which is explained by Fig. 1A. The contact mass is distributed on perforated plates which are strung upon a central round iron rod, and the pressure of the separate layers on each other by short pieces of pipe or short pegs inserted between them, so that there is only the resistance of the loose contact mass opposing the current of gas, which, however, is exceedingly slight, so that only a small mechanical force is necessary to overcome it.

This manner of filling also has the great advantage that the tubes can be filled so as to produce in all of them an equal pressure which can easily be tested in any one, so that the whole apparatus, even if consisting of a great number of such contact tubes is absolutely certain of securing an equal distribution of the gas, thus doing the best possible work.

IV. Absorption.

We come now to the question of the best method for absorbing the sulphur trioxide in the gases.

As is well known, sulphur trioxide has a much greater affinity for water than for concentrated sulphuric acid, which fact is numerically expressed by the heats of absorption.[31]

The most natural method of procedure would be, therefore, to set up in a row a number of absorption vessels in which the absorbing sulphuric acid increases in concentration in the direction of the gas current so that water or chamber acid or other dilute sulphuric acid would follow into the last vessel, and fuming sulphuric acid or acid of such strength as may be required, flow from the first.

Such a method, contrary to all appearances, does not result in the highest absorption capacity; it is, on the other hand extremely difficult to absorb sulphur trioxide completely in water or dilute sulphuric acid, for considerable quantities of white mist which will condense only with great difficulty, always leave the vessel causing considerable losses. It has been found however that sulphuric acid of a very limited range of strength, *viz.*: from 97 to 98% H_2SO_4 will absorb sulphur trioxide instantly and completely.

As is shown from the compilation of the properties of sulphuric acid in the curves, grouped together for purposes of comparison, there takes place at the abovementioned, I should like to say, critical concentration point, a whole series of changes in the properties of sulphuric acid. In the first place, at this concentration the boiling-point curve makes a remarkably sharp turn, which is characterized by the fact that at all points to its left, water or dilute sulphuric acid distil off until a strength of about 98·3% H_2SO_4 is reached, at which the acid then distils over from beginning to end at the same concentration and at the same constant boiling point of about 330°C. like a simple substance. From all strengths to the right of this point, on the other hand sulphur trioxide is distilled off until again the same concentration of 98·3% is reached.

The vapor pressure, measured at 100°C. in a vacuum, shows a minimum at

[30] German Patent No. 119.059, July 23, 1898.

[31] When 1 kg. sulphuric anhydride is mixed with much water, then are liberated about 500 calories while by the solution of 1 kg. sulphuric anhydride in much sulphuric acid of 66°B. only about 300 calories are developed.

this point, or more correctly, can scarcely be detected by ordinary means as is seen by the curve.

The specific gravity of hydrated sulphuric acid is highest at this point. It is here also that there is the greatest contraction of sulphuric acid, the electrical resistance suddenly begins to rise at this point and attains a maximum close to monohydrate with remarkable rapidity. Closely connected with this is the fact that the rapidity with which iron is attacked at this concentration reaches a minimum which of course is of the greatest importance when the durability of vessels is considered.

The absorbing power of this strength of acid is so enormous that it is possible completely to deprive a rapid current of gas of its sulphur trioxide in a single vessel, provided of course that the concentration of the acid is always kept constant at 97 to 99% H_2SO_4 by a continual addition of water and a continual removal of the excess of sulphuric acid that is formed.[32]

For making fuming sulphuric acid one or more absorption vessels must be inserted before the one kept at 97 to 99% H_2SO_4. Here, again, other very remarkable phenomena may be observed. While cast-iron vessels are well suited for use with watery sulphuric acid, resisting its action very well, they cannot be used with fuming acid of any kind, for while cast iron is attacked but little, what is much worse,—it explodes. This remarkable phenomenon is based upon the fact that oleum diffusing in the pores of the cast iron, begins the work of destruction there by being converted by the reducing action of the iron into sulphuric dioxide and hydrogen sulphide, and some times even generating carbon dioxide from the carbon of the iron, all of them gases whose critical temperatures are quite low, and as a result of this cause high tensions within the cast iron. If such a piece of iron is broken in fragments, sulphur dioxide and hydrogen sulphide are distinctly recognizable by the odor, and their evolution of gas can be perceived by immersing them in a suitable liquid. This portion of a valve shows very plainly the beginning of this action.

In contrast to cast iron, wrought iron is comparatively rapidly attacked by weak fuming acids up to oleum containing about 27% free SO_3. This action evidently has its scientific explanation in the increase of the electrical conductivity of these corrosive strengths of oleum.

A glance at the curve of the conductivity of the various concentrated acids (Fig. 2) shows that after reaching a minimum appearing as a sharp point at monohydrate, oleum again became strongly conducting, until a maximum is reached at about 10 to 15% oleum, when it again falls just as rapidly to infinitely small values. Its corrosive effect upon wrought iron (and also upon zinc) undergoes changes very similar to those in the electrical conductivity, as may be seen from the figure.

In oleum with about 27% free SO_3, wrought iron becomes practically entirely passive, and wrought iron vessels can be used for many years for manufacturing oleum of high sulphur trioxide content without being perceptibly attacked.

On these observations we based a method for the production of almost absolutely iron free sulphuric acid.[33]

[32] B. A. & S. F. Patent Anm. B. No. 28,724.

[33] B. A. & S. F. Patent Anm. No. 28,290.

Sulphuric acid has a number of other properties of general as well as practical interest, some of which are presented in the accompanying curve diagram.

Perfectly pure sulphuric anhydride is, as is perfectly well known through Rudolph Weber's researches, liquid at the ordinary temperature, melting at 17·7°C.[34]

Its melting point is raised by the addition of small quantities of water and reaches a maximum of about 27° at 85% free SO_3. These statements hold only for freshly prepared mixtures, because after standing, oleum polymerizes and then does not melt any more at all, but sublimes directly at higher temperatures, again reverting to the ordinary modification.

Continuing the dilution the melting point falls to from 0 to 2°C. and reaches a minimum at this point with oleum having 60 to 65% free sulphur trioxide and then rises again to a maximum of 36°, which unquestionably belongs to pyrosul-

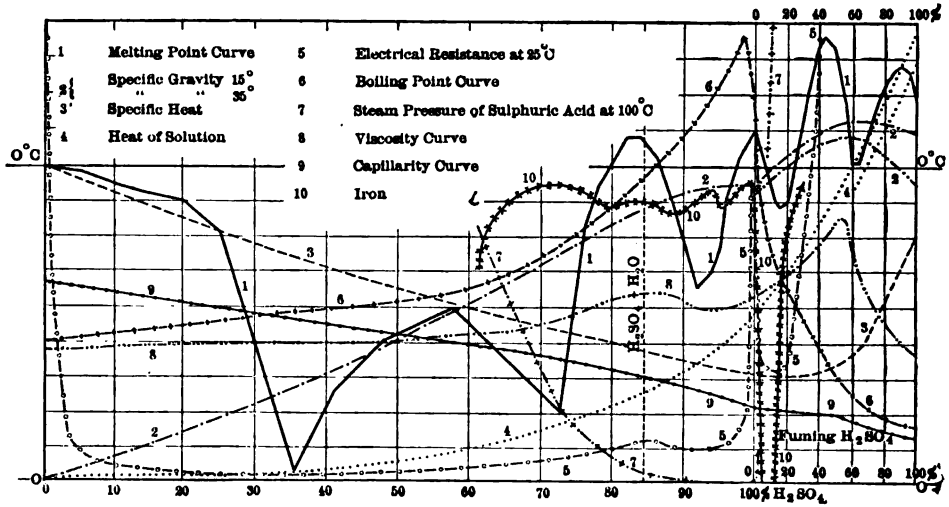


FIG. 2.—CURVES OF PHYSICAL PROPERTIES OF ORDINARY AND FUMING SULPHURIC ACID.

phuric acid, $H_2SO_4+SO_3$. This highest point is further of interest in that it corresponds very closely with the greatest density, the greatest viscosity, and a distinct angle in the curve of capillarity.

Further dilution brings us to the strengths of oleum which corrode iron, having a minimum melting point of 12°, and here the curves of electrical conductivity, corrosive effect, and melting point show similar forms. The curve then rises again and reaches a maximum of +10° at monohydrate. Still further dilution results in a decided fall of the freezing point; a minimum of —35° is reached at a concentration very familiar to us, the so-called acid 66°B. of commerce, the hydrate $2H_2SO_4+H_2O$, and then the curve rises again to +8° at the hydrate $H_2SO_4+H_2O$, to fall to below —50°, from which it rises only at 30% acid, and from 20% sulphuric acid it falls almost in a straight line to 0°. (Ac-

[34] R. Weber found the melting point to be 14·8°C., but he did not have the thermometer in the liquid. If this is the case the sulphuric anhydride all melts at 17·7°C.

cording to Thilo there seems to be another maximum at 57% $H_2SO_4+4H_2O$.)

It is noteworthy that every summit of the melting-point curve corresponds to a simple hydrate which solidifies constantly as a single substance, while the depressions of the curve represent mixtures of the neighboring hydrates combined in the form of crystals. If the crystals of the concentrations lying between the high points of the curves are examined they will be found to have a composition characteristic of concentrations at the summits of the curves. Upon this Lunge[35] based his well-known process for making monohydrate. Hydrates corresponding to the other summits could be technically produced in a similar manner, if it were still of interest to do this.

The curve of the specific heats too, has a noteworthy form, falling continuously to about 20% oleum, and then rising again to the high value of 0·77 at pure sulphuric anhydride.

The curve of the heats of solution of sulphurous acid and sulphuric acid on the other hand, is quite regular so that the formation of the various hydrates seems to have no practical effect in this.

The curve of viscosity is noteworthy in that water and sulphuric anhydride have almost the same viscosity. Its highest point lies at the greatest density of fuming sulphuric acid, with a second, lower turn at the hydrate $H_2SO_4+H_2O$.

As is evident, sulphuric acid offers such a variety in its properties that it is specially suited for purposes of instruction.

In the melting point phenomena we have an excellent illustration for presenting the theory of eutectic combinations. It can be used to present very clearly, and at the same time so as to be of the greatest value practically, the interesting phenomena of electrical conductivity, their important relations to purely technical questions, such as the degree in which metals are attacked, the phenomena of heat of solution, of variable specific heat, of various contractions of volume, as also the difference in behavior toward metals of the iron and copper group.

On several of these properties there can be based analytical methods for the determination of sulphur trioxide without the use of balance, which may often be of value in practice where specific gravity is no guide.

V. Theory of the Contact Process.

I shall proceed now to a closer consideration of the contact process itself. For this purpose allow me to present to you the details of a few fundamental experiments.

First, considering the reaction as it takes place at various temperatures and with various quantities of gas, we see that a quantitative conversion of the sulphurous acid into sulphuric anhydride cannot be accomplished under technically possible conditions, when burner gas is used, which contains besides nitrogen, a stochiometric mixture of sulphur dioxide and oxygen. This reaction is represented by the curves S and S'. Fig. 3, and we see that according to the quantity of gas, maximum yields of from 77 to 78% and from 90 to 91%, respectively, are reached. Exactly similar in behavior is a pure mixture of sulphur dioxide + oxygen; here too a quantitative conversion is impossible (curve S).

[35] German Patent No. 24,402.

If there is used, however, a gas mixture in which the oxygen or the sulphur dioxide is present in excess, it becomes possible by mass action of the one constituent to displace the other almost entirely from the mixture, by its combination with the corresponding quantity of the constituent in excess of the formation of sulphuric anhydride.

Every sulphuric acid contact process will then be the more successful, the more oxygen there is in the gas mixture in proportion to the sulphurous acid, while the nitrogen has no influence on the reaction.[36]

Let us consider now the behavior of a technical burner gas such as is obtained in roasting pyrites and in which the relation of the quantity of the sulphur dioxide present to the quantity of oxygen is as $2SO_2 : 3O_2$, corresponding to a composition by volume of 7% SO_2, 10% O, and 83% of nitrogen. If we allow this mixture to pass through an empty, uniformly heated porcelain tube, we perceive even under this condition the formation of some sulphur dioxide at certain temperatures, though it is very slight in quantity.

The results of this experiment are represented by the curve *P*, Fig. 3.

As a further experiment we fill the tube with a platinum contact substance, for example, platinized asbestos,[37] and now traverse all temperatures which need to be considered. With a rise of temperature the rapidity of the reaction increases, so that even at 380 to 400°C. nearly all the sulphur dioxide is found to be converted into sulphur trioxide. From 400 to 430°C. the reaction remains nearly uniformly quantitative, a conversion of from 98 to 99% being maintained; above this, however, there is a distinctly perceptible decomposition of sulphuric anhydride into the components, the curve falls again, though not as abruptly as it rose before. At from 700 to 750°C. only about 60% of the sulphurous acid is transformed into sulphuric anhydride, and at about 900 to 1,000°C. the curve reaches the zero mark, and no reaction between sulphur dioxide and oxygen can any longer be detected.

If we repeat this experiment under exactly the same circumstances but with smaller quantities of contact mass, or what amounts to the same thing,—with larger quantities of gas, we get a series of curves, 2, 3, 4, 5, 6 (Fig. 3), whose left and right portions have an entirely different appearance. For while the portions of the curves up to their highest points are approximately parallel to each other, they are seen to diverge somewhat if examined more closely, which points to a common origin; the decomposition side of the curves converge and finally all unite at about the same temperature, between 900 and 1,000°C. the zero point of the reaction.

If we follow the highest points of the curves, we notice a peculiar movement of their maxima with decreasing quantities of platinum in the direction of an increasing temperature and likewise a marked decrease in the highest attainable percentage of sulphuric anhydride formed. If these maxima are connected by a curve, this will on the left systematically approach the theoretically possible

[36] The formula $SO_2+O=SO_3$ accordingly does not express the conditions existing here, but should be written, $2SO_2+nO_2=2SO_3+(n-1)O_2$, where n should not be less than 2.

[37] For such an experiment there should be taken such a quantity of from 5 to 10% platinized asbestos that there is about 0·5 g. platinum in the farther half of the tube, while the first half remains empty and serves to preheat the gases.

conversion of 100%, while on the right its direction is toward a point in the neighborhood of 600°C. The convergence of the curves on the decomposition side leads to the conjecture that the decomposition of sulphurous anhydride becomes more and more independent of the contact substance that is used and develops into a function purely of temperature.

The correctness of such a conjecture could be tested very simply by a repetition of the experiment with the platinum left out, but for this test the mixture of gas must previously be brought into a condition of an almost complete conversion of the sulphurous acid into sulphuric anhydride before beginning the experiment.

This experiment was tried with a very surprising result. A curve was obtained which is moved to the right by several hundred degrees and falls strongly only at from 800 to 900°C. without, however, completely reaching the zero point at the temperature of from 1,100 to 1,200°C. which was at our disposal.

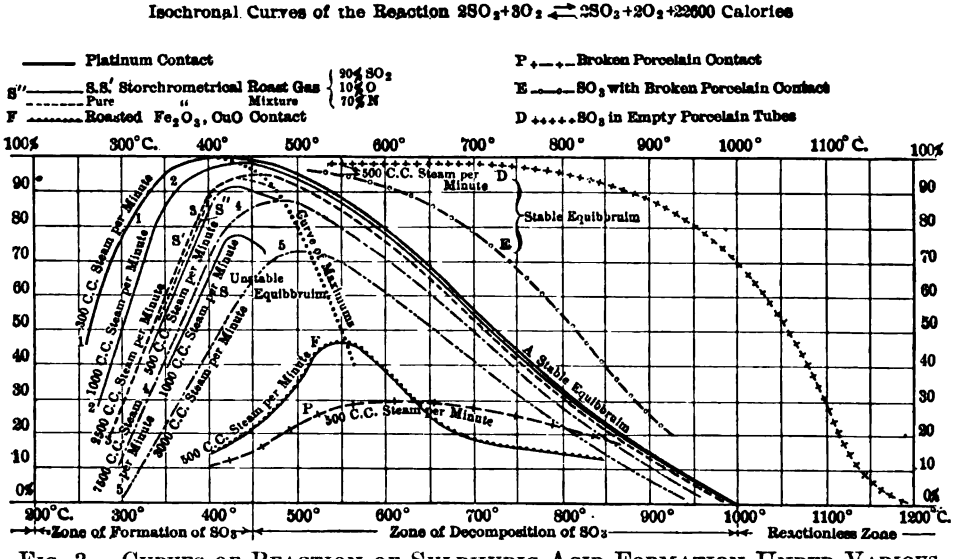

Isochronal Curves of the Reaction $2SO_2+3O_2 \rightleftarrows 2SO_3+2O_2+22600$ Calories
Platinum Contact
S'' S.S' Storchrometrical Roast Gas { 90% SO2, 10% O, 70% N
Pure " Mixture
F Roasted Fe2O3, CuO Contact
P Broken Porcelain Contact
E SO3 with Broken Porcelain Contact
D SO3 in Empty Porcelain Tubes
100% 300°C. 400° 500° 600° 700° 800° 900° 1000° 1100° C.
300 C.C. Steam per Minute
500 C.C. Steam per Minute
Stable Equilibrium
Unstable Equilibrium
Curve of Maximums
1000 C.C. Steam per Minute
2000 C.C. Steam per Minute
1800 C.C. Steam per Minute
3000 C.C. Steam per Minute
400 C.C. Steam per Minute
A Stable Equilibrium
Zone of Formation of SO3
Zone of Decomposition of SO3
Reactionless Zone

FIG. 3.—CURVES OF REACTION OF SULPHURIC ACID FORMATION UNDER VARIOUS CONDITIONS.

The once formed sulphuric anhydride, therefore, is very stable at high temperatures in the absence of contact substances. Consequently we have here an unstable equilibrium which is quickly destroyed by any contact substance and tends to become a stable equilibrium. The curve *E* shows this influence by the gradual approach of the curve *D* toward *S* when the same experiments as those giving curve *D* were tried but with a tube filled with fragments of porcelain. These phenomena call to mind those of overfusion and of delay in boiling of liquids heated above their boiling points. Porcelain and other substances evidently seem to act as catalysors, very much as does platinum, at these temperatures. Still it is very remarkable that at the high bright red temperatures that were used, a condition of unstable equilibrium should not become one of stable equilibrium more readily.

The formation of sulphur trioxide, as shown by curves, 1, 2, 3, and 4, is

dependent upon the length of time of contact of the gases with the contact substance.

A very simple means of getting a clear view of the changes taking place in the conversion is obtained by representing the results for different lengths of time isothermally, *i.e.*, by letting the *X* axis represent length of time, or what comes to the same thing, the quantity of platinum, and the *Y* axis the quantity of sulphur dioxide converted into sulphur trioxide.

In this way a group of curves (Fig. 4) is obtained, which shows at a glance the length of time or the quantity of platinum necessary for a certain percentage of conversion at a certain temperature. The form of the curves shows further that these begin at zero and continue indefinitely, being parallel to the *X* axis and symmetrically approaching the maximum corresponding to that particular temperature.

It is further shown that with rising temperatures and with increasing con-

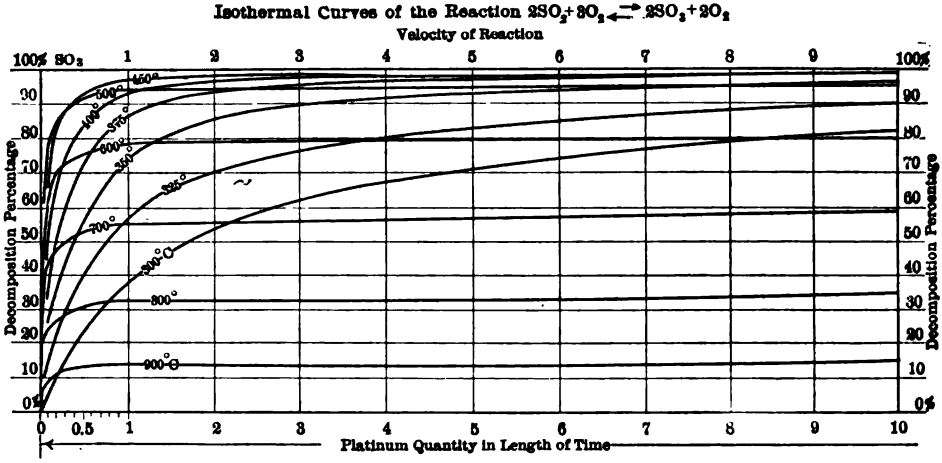


FIG. 4.—ISOTHERMAL CURVES OF THE REACTION $2SO_2+3O_2$— —$2SO_3+2O_2$.

tent of sulphuric anhydride, the curves turn more and more, thus deviating more and more from a complete conversion. Finally, the speed with which the reaction begins becomes so great that the first portion of the curves almost coincides with the *Y* axis at higher temperatures. The first meeting of the burner gas with the contact mass must be accompanied then by a very violent reaction, and here takes place the great rise in temperature of the first portions of the contact mass which may become heated to redness, depending on the manner of exterior cooling. It follows further from these curves for this very reason, that with the formerly generally used red heat of the contact furnaces a quantitative reaction was impossible, and it is only sulphur trioxide itself that exerts a retarding influence on the speed of the reaction.

As the important result of these experiments, a line of stable equilibriums is shown which divides the whole range of temperatures into two divisions. Temperatures below 200°C, and above from 900 to 1,000°C. may be regarded as resulting, technically, in no reaction; between 200 and 450°C. the reaction of for-

mation preponderates, while above this the decomposition of the sulphuric anhydride rapidly becomes prominent.

Important technical conclusions can be drawn from these facts, for, even if the boundary line *A* has been determined for a particular technical gas mixture, the various modifications occurring in practice will scarcely have a very great influence in the position of this stable equilibrium. Further it is evident that this boundary line must theoretically and practically be independent of the kind of contact material; from which it follows, that only such contact substances will be capable of bringing about an approximately quantitative reaction in a single operation, as have their highest activity at the temperature of the zone of formation, that is under about 450°C. All contact substances that develop their maximum power only beyond this temperature will never be able to bring about a quantitative yield, however long they remained in contact with the gases.

At present there is only one contact substance which fulfills these conditions, namely, platinum; nor can this be replaced by any of the other metals of the platinum group even with approximately good results.

At the close of my lecture may I be permitted to present to you the development in the manufacture of sulphuric acid that has taken place in the works of the Badische Anilin & Soda Fabrik alone since the discovery of the contact process which I have described. The yearly production of sulphur trioxide by this concern has been as follows: 1888, 18,500 tons; 1894, 39,000 tons; 1899, 89,600 tons; and 1900, 116,000 tons.

For the development of such an enterprise the energy of any single individual would, of course, have been insufficient. The powerful assistance was necessary of a concern such as the Badische Anilin & Soda Fabrik, guided by the foresight of a Heinrich Brunck, the wide experience of a Gustav Jacobsen, and the expert assistance of prominent engineers was necessary in order to achieve the success which I have described and which is an honor to our national industry.

Laboratory Determinations.

Melting Points.—To determine the melting points, a glass cylinder containing the acid and a movable thermometer graduated to tenths of a degree, was immersed in a cooling bath. First were noted the temperatures to which the acid could be cooled with stirring without freezing (overcooling) (see accompanying curve, Fig. 4). As soon as the first crystals were formed, the cylinder was removed from the cooling bath and, with continual stirring, the highest temperature was noted to which the thermometer rose to remain constant even with the further formation of crystals. (Melting temperature, see table.) Then the crystals were again melted by careful warming and the temperature noted at which the last portions melted. (Higher melting-point curve, Fig. 4.)

Specific Gravity.[38]—Method: Weighing with brass weights in air at 15°C. in a narrow-necked graduated flask containing 500 c.c. which had been calibrated by weighing with water at 15°C. (I was assisted by Dr. Seitz and Dr. Slama in these determinations.)

[38] See also Lunge & Isler. *Lunge's Handbuch*, 1893, p. 107, and W. Kohlrausch, *Wiedermann's Annalen*, 7-69, 1882.

MELTING POINT OF ORDINARY AND FUMING SULPHURIC ACID OF FROM 0 TO 100% SO_3.

Sulphuric Acid.								Oleum.	
Total SO_3.	Melting Point.	Total SO_3.	Melting Point.	Total SO_3.	Melting Point.	Total SO_3.	Melting Point.	Total SO_3.	Melting Point.
%		%		%		%		%	
1	— 0·60	18	—13·2	70	+ 4·0	85	—11·0	0	+10·0
2	— 1·0	19	—15·2	71	— 1·0	86	— 2·2	5	+ 3·5
3	— 1·7	20	—17·1	72	— 7·3	87	+13·5	10	— 4·8
4	— 2·0	21	—22·5	73	—16·2	88	+26·0	15	—11·2
5	— 2·7	22	—31·0	74	—25·0	89	+34·2	20	—11·0
6	— 3·6	23	—40·1	75	—34·0	90	+34·2	25	— 0·6
7	— 4·4	.....	Under	76	—32·0	91	+25·8	30	+15·2
8	— 5·3	.....	—40·0	77 *a*	—28·2	92	+14·2	35	+26·0
9	— 6·0	61	—40·0	78	—16·5	93	+ 0·8	40	+33·8
10	— 6·7	62	—20·0	79	— 5·2	94	+ 4·5	45	+34·8
11	— 7·2	63	—11·5	80	+ 3·0	95	+14·8	50	+28·5
12	— 7·9	64	— 4·8	81	+ 7·0	96	+20·3	55	+18·0
13	— 8·2	65	— 4·2	81·63	+10·0	97	+29·2	60	+ 0·7
14	— 9·0	66	+ 1·2	82	+ 8·2	98	+33·8	65	+ 0·8
15	— 9·3	67	+ 8·0	83	— 0·8	99	+36·0	70	+ 9·0
16	— 9·8	68	+ 8·0	84	— 9·2	100	+40·0	75	+17·2
17	—11·4	69	+ 7·0					80	+22·0
								85	+33·0 (27°) *b*
								90	+34·0 (27·7°)
								95	+36·0 (26°)
								100	+40·0 (17·7°)

(*a*) So-called 66° B. (*b*) The numbers in parenthesis denote the melting points of the not yet polymerized, freshly prepared oleum.

SPECIFIC GRAVITY OF FUMING SULPHURIC ACID AT 35°C.

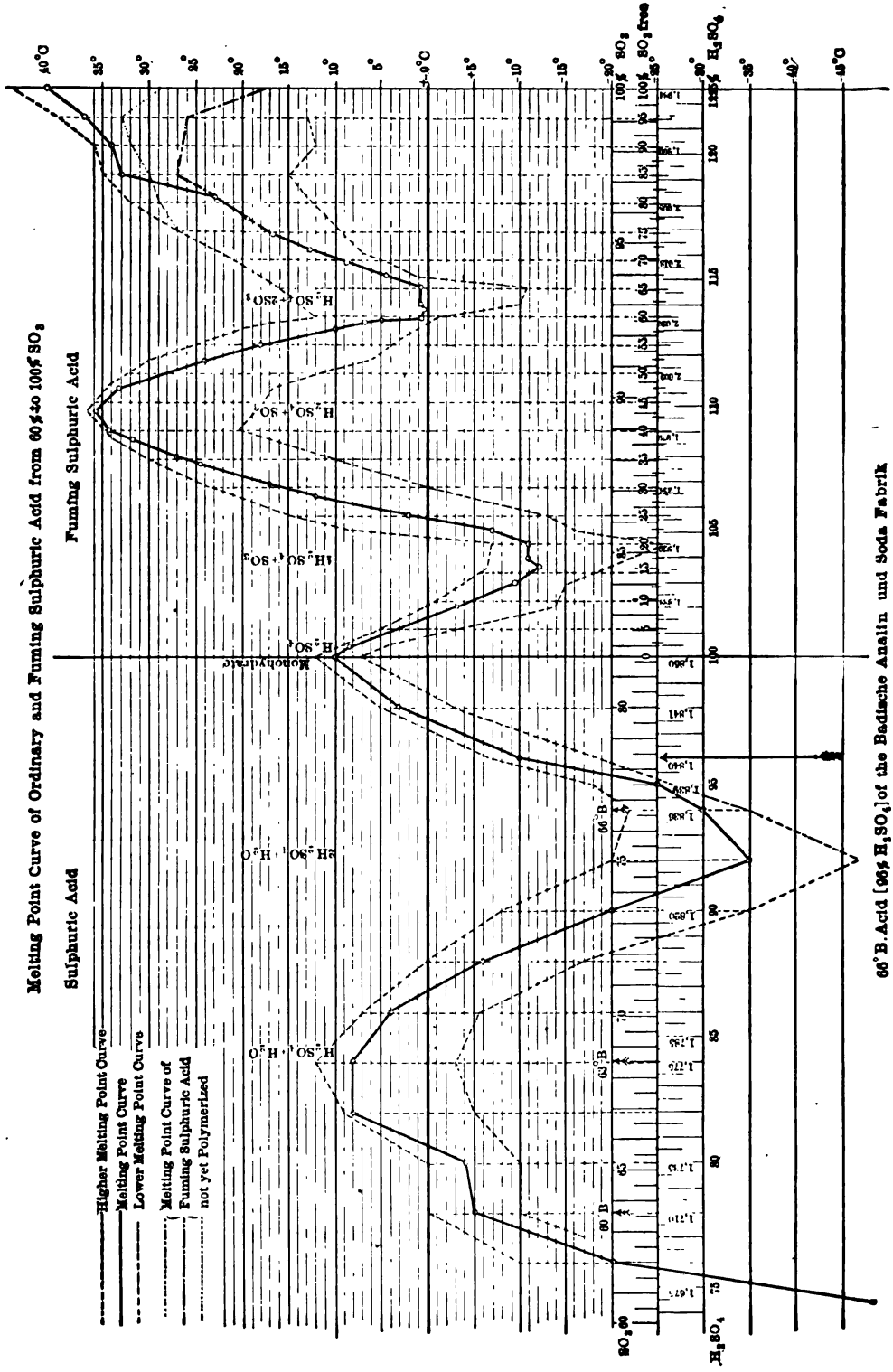
Total SO_3.	Free SO_3.	Specific Gravity.	Total SO_3.	Free. SO_3.	Specific Gravity.	Total SO_3.	Free. SO_3.	Specific Gravity.	Total SO_3.	Free. SO_3.	Specific Gravity.
%	%		%	%		%	%		%	%	
81·63	0	1·8186	86·40	26	1·9158	91·18	52	1·9749	95·95	78	1·9315
81·99	2	1·8270	86·76	28	1·9220	91·55	54	1·9760	96·32	80	1·9251
82·36	4	1·8360	87·14	30	1·9280	91·91	56	1·9772	96·69	82	1·9188
82·73	6	1·8425	87·50	32	1·9338	92·28	58	1·9754	97·05	84	1·9115
83·09	8	1·8498	87·87	34	1·9405	92·65	60	1·9738	97·42	86	1·9046
83·46	10	1·8565	88·24	36	1·9474	93·02	62	1·9709	97·78	88	1·8980
83·82	12	1·8627	88·60	38	1·9534	93·38	64	1·9672	98·16	90	1·8888
84·20	14	1·8692	88·97	40	1·9584	93·75	66	1·9638	98·53	92	1·8800
84·56	16	1·8756	89·33	42	1·9612	94·11	68	1·9600	98·90	94	1·8712
84·92	18	1·8830	89·70	44	1·9643	94·48	70	1·9564	99·26	96	1·8605
85·30	20	1·8919	90·07	46	1·9672	94·85	72	1·9502	99·63	98	1·8488
85·66	22	1·9020	90·44	48	1·9702	95·21	74	1·9442	100·00	100	1·8370
86·03	24	1·9092	90·81	50	1·9733	95·58	76	1·9379			

SPECIFIC GRAVITY OF CONCENTRATED AND FUMING SULPHURIC ACID AT 15°C. AND 45°C.

H_2SO_4.	Total SO_3.	Free SO_3.	Specific Gravity, 15° C.	Specific Gravity, 45° C.	H_2SO_4.	Total SO_3.	Free SO_3.	Specific Gravity, 15° C.	Specific Gravity, 45° C.
%	%	%			%	%	%		
95·98	78·35	.....	1·8418	.....	.....	85·30	20·0	1·920	1·887
96·68	78·92	.....	1·8429	.....	.....	87·14	30·0	1·957	1·920
96·99	79·18	.....	1·8431	.....	.....	88·97	40·0	1·979	1·945
97·66	79·72	.....	1·8434 Max.	.....	.....	90·81	50·0	2·009	1·964 Max.
98·65	80·53	.....	1·8408	.....	.....	92·65	60·0	2·020 Max.	1·959
99·40	81·14	.....	1·8308 Min.	.....	.....	94·43	70·0	2·018	1·942
99·76	81·44	.....	1·8418	.....	.....	96·32	80·0	2·008	1·890
100·00	81·63	.....	1·8500	1·821	.....	98·16	90·0	1·990	1·864
.....	83·46	10·0	1·888	1·858	.....	100 00	100·0	1·984	1·814

Specific Heat.[39]—Method: The calorimeter consisted of a vessel of sheet zinc protected against radiation by means of felt and containing 2 kg. water at room temperature (about 18°); about 1 kg. of the acid to be examined was warmed in a flask to something over 35°C. with shaking (calibrated thermometer reading to 0·1° was used) and then quickly immersed in the calorimeter water and allowed

[39] Values for watery sulphuric acid, see *Lunge's Handbuch*, 1893, p. 123.


Melting Point Curve of Ordinary and Fuming Sulphuric Acid from 60% to 100% SO_3
Sulphuric Acid
Fuming Sulphuric Acid
Higher Melting Point Curve
Melting Point Curve
Lower Melting Point Curve
Melting Point Curve of Fuming Sulphuric Acid not yet Polymerized
Monohydrate
H_2SO_4
$H_2SO_4 + SO_3$
$H_2SO_4 + 2SO_3$
$2H_2SO_4 + H_2O$
$H_2SO_4 + H_2O$
66° B. Acid [96% H_2SO_4] of the Badische Anilin und Soda Fabrik

to cool to 25°C., again with shaking, and then removed from the calorimeter. The temperature measurements in the calorimeter were taken with a Beckman's thermometer divided into 0·01 of a degree, the scale of which had been tested for correctness. The indicated temperature was corrected by the temperature of the different parts of the calorimeter and flasks used.

Example: 1 kg. oleum, 70% free SO_3 was cooled from 35 to 25°C. in 2 kg. of water. There were found in four experiments changes in temperature of:

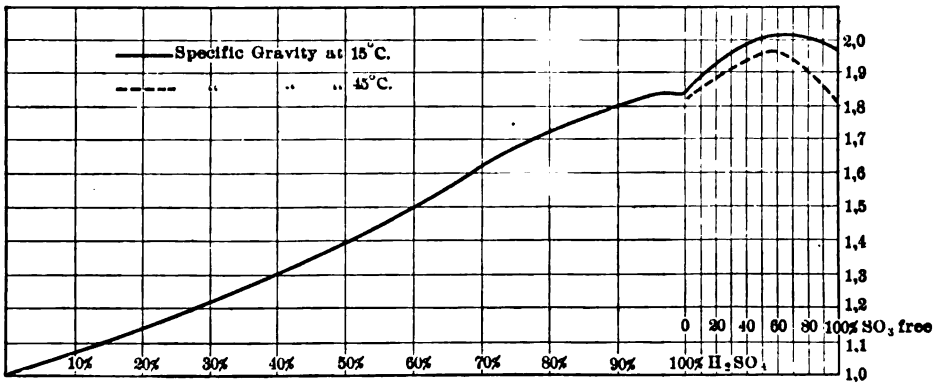
2·41°C., 2·41°C., 2·41°C., and 2·42°C.; average, 2·4125°C.
Multiplying.....2·4125+2=4·825 calories.
Correction for calorimeter +0·045
4·8700
Correction for flask..... −0·1500
Specific heat..... 0·4720 at 35°C.(to 25°C.

SPECIFIC HEAT.

Total SO_3.	Free SO_3.	Specific Heat.	Total SO_3.	Free SO_3.	Specific Heat.	Total SO_3.	Free SO_3.	Specific Heat.	Total SO_3.	Free SO_2.	Specific Heat.
%	%		%	%		%	%		%	%	
76·8	.....	*a* 0·3691	85·48	20·95	*a* 0·3391	91	51·00	0·370			
78·4	.....	*a* 0·3574	89	23·78	0·340	93	56·45	0·400	96·52	81	*a* 0·5596
80	.....	0·350	87·13	29·74	*a* 0·3392	93	61·89	0·425	97	88·67	0·590
89·0	.....	*a* 0·3574	88	34·67	0·350	93·3	63·5	*a* 0·4325	97·99	88 6	*a* 0·6526
81·5	.....	0·3478	88·75	38·75	*a* 0·3498	94	67·34	0·455	98	89·12	0·650
82	2·0	0·345	90	45·56	0·360	94·64	70·06	*a* 5·4780	99	94·56	0·710
83·46	10·0	*a* 0·3417	91·1	46·1	*a* 0·3599	95	72 78	0·495	99·8	98·9	*a* 0·7413
84	12·89	0·340	90·73	49·4	*a* 0·3660	96	78·23	0·585	100	100	0·770

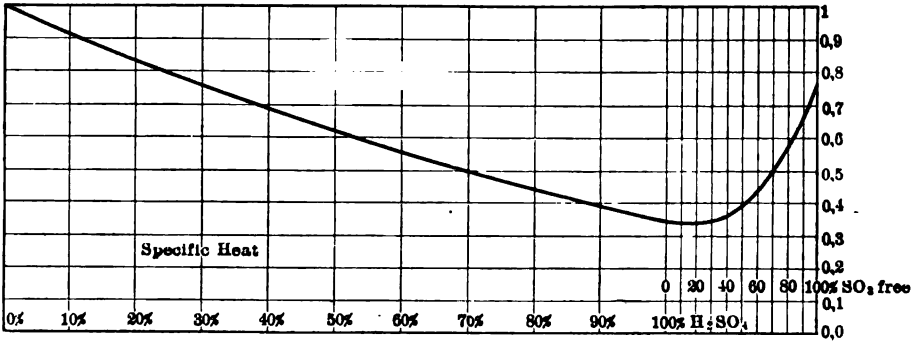
(*a*) Values interpolated.

Heat of Solution.—Method: The calorimeter consisted of a glass flask of about 8 liters capacity, set up to its neck into a vessel of sheet metal, carefully insulated by means of felt and containing from 5 to 6 kg. of water at room temperature



(from 18 to 22°C.). The whole apparatus could be lifted by means of the sheet metal vessel and shaken. According to the concentration of the acid from 40 to 15 g. of acid were used which were sealed up in a thin walled glass bulb ending in two capillary tubes. After breaking off the two capillary ends the acid was allowed to flow out under the surface of the water in the calorimeter as quickly as possible, being forced out by means of dry air if necessary. Finally the glass bulb and the capillary tubes joined to it were quickly broken and thrown into the calorimeter. The apparatus was then shaken up and the highest temperatures

read by means of a Beckman's thermometer divided into hundredths of a degree. Corrections were made for the water equivalent of the calorimeter and the



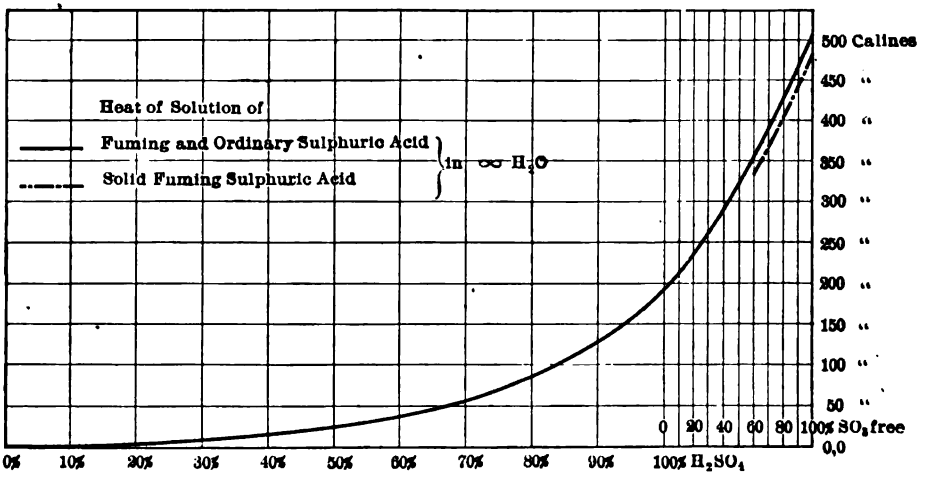
thermometer. The weights were not reduced to a vacuum because the error amounted to less than 10% of the experimental error. Two titrations of the acid, independent of each other, were made and the avrag etaken.

Example:—

40·247 g. oleum, 91·07% SO_3=51·38% free SO_3.
43·758 g. oleum, 91·07% SO_3=51·38% free SO_3.
Increase of temperature in calorimeter containing 5 kg. H_2O=2·610° and 2·835°.

Calories found	13·050	14·175
Correction for calorimeter	0·155	0·1647
	13·205	14 3397
Calories due to 1 kg. acid	328·09	327·70
Average		327·895

In determining the heats of solutions of solid oleum which however solidifies



completely only at temperatures lower than the room temperature, the loss of heat due to this cause was of course included in the calculations.

The determinations were also made on a large scale. A wooden cask or hogs-

HEAT OF SOLUTION.

H_2SO_4.	SO_3.	Free SO_3.	Calories.	H_2SO_4.	SO_3.	Free SO_3.	Calories.
%	%	%		%	%	%	
50·32	41·07	.....	40·45	.....	85·26	19·75	245·27
60·18	49·12	.....	65·46	.....	87·31	30·91	277·6
63·86	52·13	.....	79·05	.....	89·08	40·55	299·05
70·24	57·33	.....	110·05	.....	91·05	51·28	327·9
73·76	60·21	.....	132·3	.....	92·67	60·10	361·4
76·86	62·74	.....	151·4	.....	94·72	71·26	393·6
79·41	64·82	.....	171·7	.....	96·62	81·60	433·5
99·88	81·62	0·0	194·06	.....	98·48	97·81	470·6
.....	83·49	10·12	221·4	.....	99·04	99·48	491·1

HEAT OF SOLUTION OF SOLID FUMING SULPHURIC ACID.

Total SO_3.	Free SO_3.	Calories.	Total SO_3.	Free SO_3.	Calories.
%	%		%	%	
89·4	42·3	271·0	96·28	79·75	408·8
90·73	49·53	303·2	98·14	97·32	436·1
92·5	59·2	330·4	99·54	99·34	481·4
94·5	70·1	369 2	99·84	99·77	486·0

head having a capacity of 500 liters was filled with 400 liters of water and closed by means of a wooden cover. The weighing was done on a platform scales which had been calibrated. The water in this calorimeter remained constant in temperature for a very long time after having been stirred with a wooden stirrer.

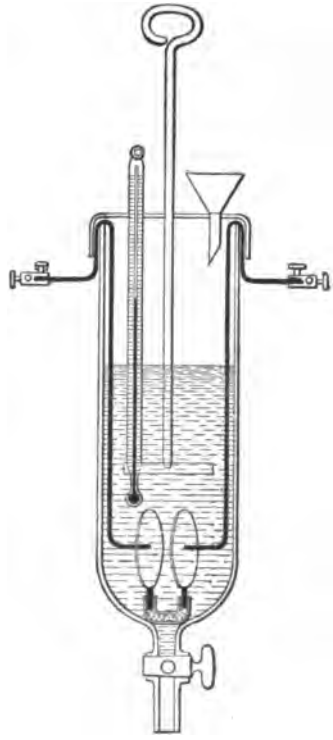


FIG. 5.—APPARATUS FOR MEASURING ELECTRIC RESISTANCE OF SULPHURIC ACID.

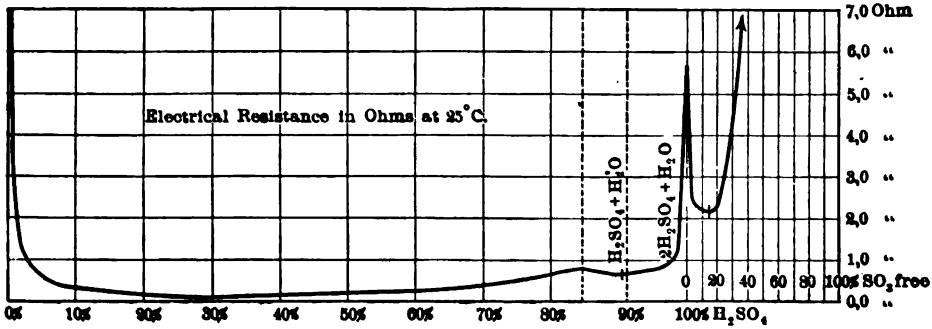
A corresponding quantity of acid about 1 or 2 kg., was then added and the temperature taken with a Beckman's thermometer divided into hundredths of a degree. The results of these two methods corresponded very well, and so have

not been kept separate. It may be stated however that the methods of determining the heats of solution on a large scale is much simpler, and if the weighing is sufficiently close, at least as accurate as the ordinary method on a small scale.

HEAT OF SOLUTION OF ORDINARY AND FUMING SULPHURIC ACID.

SO_3.	H_2SO_4.	Calories.	SO_3.	H_2SO_4.	Calories.	SO_3.	Free SO_3.	Calories.	Heat of Solutions of Solid Oleum. Cal.
%	%		%			%	%		
50	61·25	39	67	82·08	93	82	2·0	199	.....
51	62·48	41	68	83·30	98	83	7·5	210	.....
52	63·70	44	69	84·53	103	84	12·9	223·5	.....
53	64·98	46·5	70	85·75	108	85	18·3	237·5	.....
54	66·15	49	71	86·98	113	86	23·8	250	.....
55	67·38	51·5	72	88·20	119	87	29·2	265	.....
56	68·60	54	73	89·43	126	88	34·7	278	.....
57	69·83	57	74	90·65	133	89	40 1	292	.....
58	71·05	59·5	75	91·88	139	90	45·6	308	296
59	72·28	62	76	93·10	146	91	51·0	325	304
60	73·50	65	77	94·33	152	92	56·4	344	322
61	74·73	68	78	95·55	160	93	61·9	363	340
62	75·95	72	79	96·78	168	94	67·3	381	360
63	77·18	75	80	98·00	178	95	72·8	401	380
64	78·40	79	81	99·23	188	96	78·3	421	402
65	79·63	83·5	81·63	100·00	193	97	83·7	442	423
66	80·85	88				98	89·1	465	442
						99	94·6	490	463
						100	100·0	515	486

Electrical Resistance.—The measurements of the electrical resistance of sulphuric acid was made in the usual manner with an alternating current and a Wheatstone bridge with telephone, in an apparatus of glass with electrodes of circular platinum plates 4 cm. in diameter and 1·5 cm. apart. The arrangement of the parts of the apparatus is shown by Fig. 5. In order to be able to empty and wash the apparatus most conveniently, a glass stopcock was attached at the bottom. The distance between the electrodes was made constant by means of platinum wires attached to them and melted into a U-shaped piece of glass tubing.



It was possible to measure differences of 0·02 ohm with sufficient accuracy. For monohydrate a slight deviation from the values given by Kohlrausch[40] was found, the maximum resistance being at from 99·9 to 99·95% H_2SO_4 instead of at from 99·74 to 99·75% H_2SO_4. For these determinations the purest obtainable sulphuric acid, made from gaseous SO_3 was used. Otherwise the figures agree well with those of Kohlrausch. The determinations have been extended to 100% SO_3. These measurements were made in company with Dr. Bazlen.

[40] Particular attention is called to the exact investigations by W. Kohlrausch in *Wiedermann's Annalen*, 17-69, 1882.

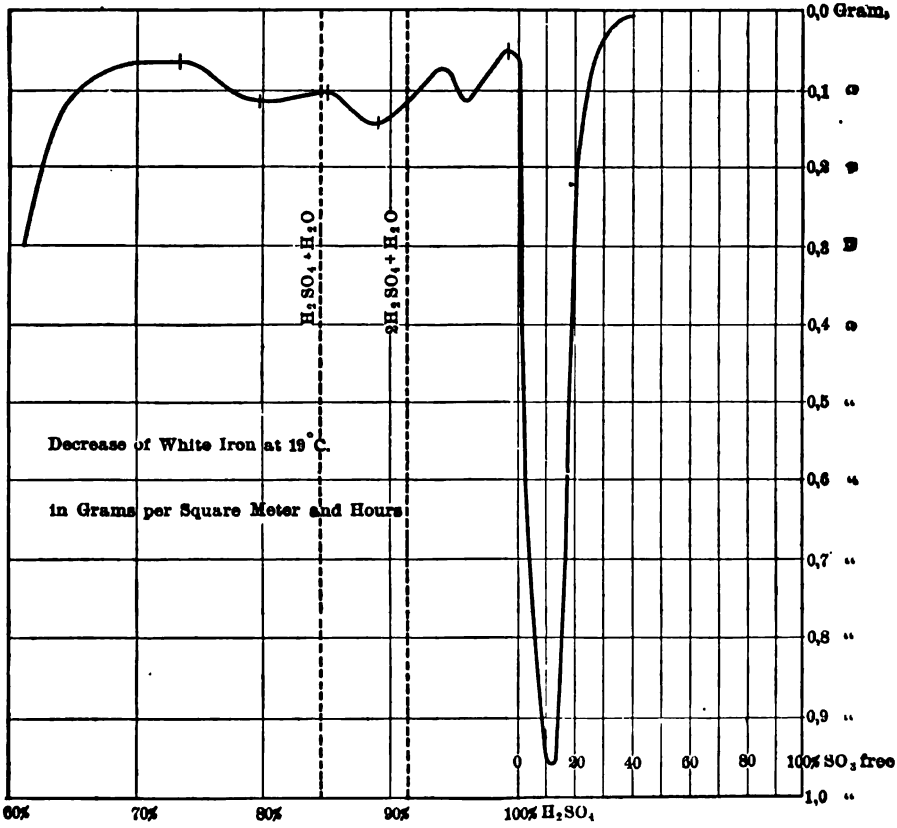
ELECTRICAL RESISTANCE OF SULPHURIC ACID AT 25°C.

SO_3.	H_2SO_4.	Ohm.	SO_3.	H_2SO_4.	Ohm.	SO_3.	H_2SO_4.	Ohm.	SO_3.	H_2SO_4.	Ohm.
%	%		%	%		%	%		%	%	
40·19	49·23	0·235	65·14	79·8	0·67	75·1	97·01	0·70 Min.	81·27	99·55	2·2
48·80	59·79	0·29	67·04	82·14	0·74	76·73	94·0	0·72	81·345	99·64	2·7
53·27	65·14	0·345	68·53	83·97	0·75	78·45	96·11	0·795	81·425	99·74	3·5
57·54	70·55	0·43	69·12	84·68	0·76 Max.	78·52	96·2	0·79	81·455	99·78	4·2
60·28	73·85	0·475	70·23	86·03	0·745	79·55	97·46	0·80	81·53	99·87	5·7
61·07	74·82	0·525	70·84	86·79	0·74	80·22	98·27	1·10	81·535	99·88	5·7
64·0	78·4	0·60	72·4	89·92	0·705	80·98	99·21	1·95	81·59	99·95	7·45 Max.

ELECTRICAL RESISTANCE OF FUMING SULPHURIC ACID AT 25°C.

Total SO_3.	Free SO_3.	Ohm.	Total SO_3.	Free SO_3.	Ohm.	Total SO_3.	Free SO_3.	Ohm.	Total SO_3.	Free SO_3.	Ohm.
%	%		%	%		%	%		%	%	
81·695	0·34	6·15	85·2	19·4	2·23	90·5	45·0	23·4	94·4	69·6	759
81·74	0·5	3·35	86·3	25·5	2·95	90·8	50·0	53·0	95·4	75·0	1,365
82·4	4·0	2·43	87·05	29·5	4·05	91·6	54·0	88·0	96·35	80·0	4,000 at 27°.
83·44	9·8	2·20	88·3	36·3	6·65	92·7	60·3	220	96·87	88·0	6,650 at 32°.
84·2	14·0	2·15 } Min.	89·0	40·2	15.2	93·4	64·0	287	98·16	90·0	61,950 at 36°.
84·7	16·7	2·15 }									

Corrosive Effect upon Iron.—For these experiments there were used prismatic iron rods 10×10×10 mm., whose surface had been planed and smoothed. After



being freed from grease by means of caustic soda and alcohol, they were dried in a dessicator, weighed and laid for 72 hours in the acid whose corrosive effect

was to be determined. Then the acid was poured out, the rods washed with an excess of soda solution, hot water and alcohol, and carefully rubbed off with a cotton cloth. They were then dried in a dessicator and finally weighed. The

DECREASE IN WEIGHT OF WHITE IRON AT 19°C. IN GRAMS PER SQUARE METER AND HOURS.

H_2SO_4.	SO_3.	Cast Iron.	Ingot Iron.	Welded Iron.	H_2SO_4.	SO_3.	Cast Iron.	Ingot Iron.	Welded Iron.
%	%				%	%			
48·8	39·9	0·2177	.....	.....	99·30	81·07	0·057	0·042	0·050
61·2	50·0	0·1510	.....	0·3032	99·50	81·25	0·060	0·038	0·049
67·7	55·3	0·0947	.....	0·0789	99·77	81·45	0·066	0·042	0·049
73·4	59·9	0·0662	.....	0·0623	100·00	81·63	0·087	0·068	0·076
79·7	65·0	0·1560	.....	0·1159	*a* 81·8	*b* 0·91	0·201	0·308	0·323
83·7	68·4	0·1388	.....	0·1052	82·02	2·00	0·190	0·285	0·514
85·1	69·5	0·1306	.....	0·1034	82·28	3·64	0·132	0·441	0·687
88·2	72·0	0·1636	.....	0·1417	82·54	4·73	0·154	0·956	1·075
90·6	73·9	0·1760	.....	0·1339	82·80	7·45	0·151	0·566	1·321
92·0	75·2	0·0983	.....	0·1040	83·50	10·17	0·079	0·758	1·540
93·0	75·9	0·0736	0·0987	0·0855	84·20	12·89	0·270	1·024	0·892
94·1	77·0	0·0723	0·0933	0·0706	84·62	16·16	0·271	1·400	0·758
95·4	77·9	0·1274	0·1471	0·1209	85·05	18·34	0·076	1·988	1·530
96·8	79·0	0·1013	0·0815	0·0988	86·00	23·78	0·070	0·245	0·471
98·4	80·3	0·0681	0·0533	0·0655	88·24	34·67	0·043	0·033	0·053
98·7	80·6	0·0583	0·0509	0·0570	90·07	45·56	0·040	0·018	0·019
99·2	81·0	0·0568	0·0418	0·0504					

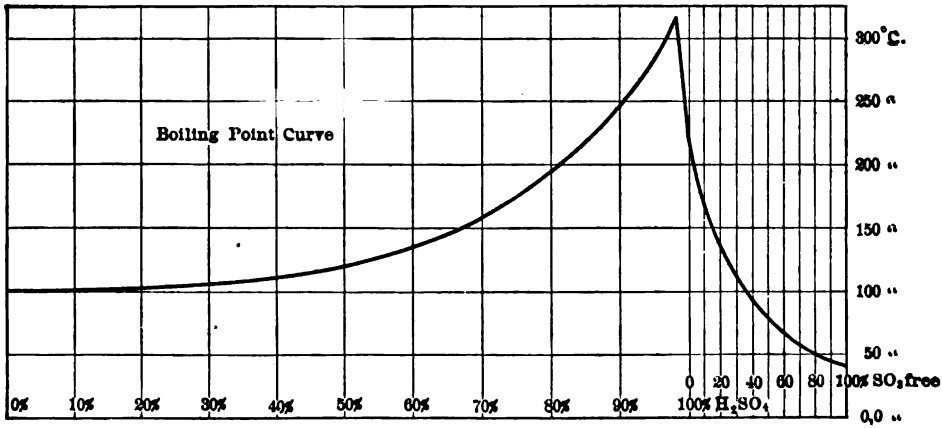
(*a*) Total SO_3. (*b*) Free SO_3.

BOILING POINT.

H_2SO_4.	SO_3.	Free SO_3.	Melting Point.	Barometic Pressure.	H_2SO_4.	SO_3.	Free SO_3.	Melting Point.	Barometric Pressure.
%	%	%		Mm.	%	%	%		Mm.
61·69	50·36	.....	140	750	.....	82·3	3·64	212	759
70·90	57·88	.....	162	750	.....	83·4	9·63	170	759
81·49	66·44	.....	202	750	.....	86·45	26·23	125	759
89·23	72·84	.....	240	750	.....	89·5	42·84	92	759
96·26	78·56	.....	292	750	.....	93·24	63·20	60	759
98·54	80·44	.....	317	750	.....	99·5	97·2	43	759
99·91	81·56	.....	273	753					

experiments were carried out together with H. Schulze, Dr. Scharff and Dr. Slama.

Boiling Points.—The temperature indicated at the first ebullition by a ther-



mometer dipped into the liquid was taken as the boiling point. If the liquid is allowed to boil with a reflux condenser, slightly higher values are obtained.[41]

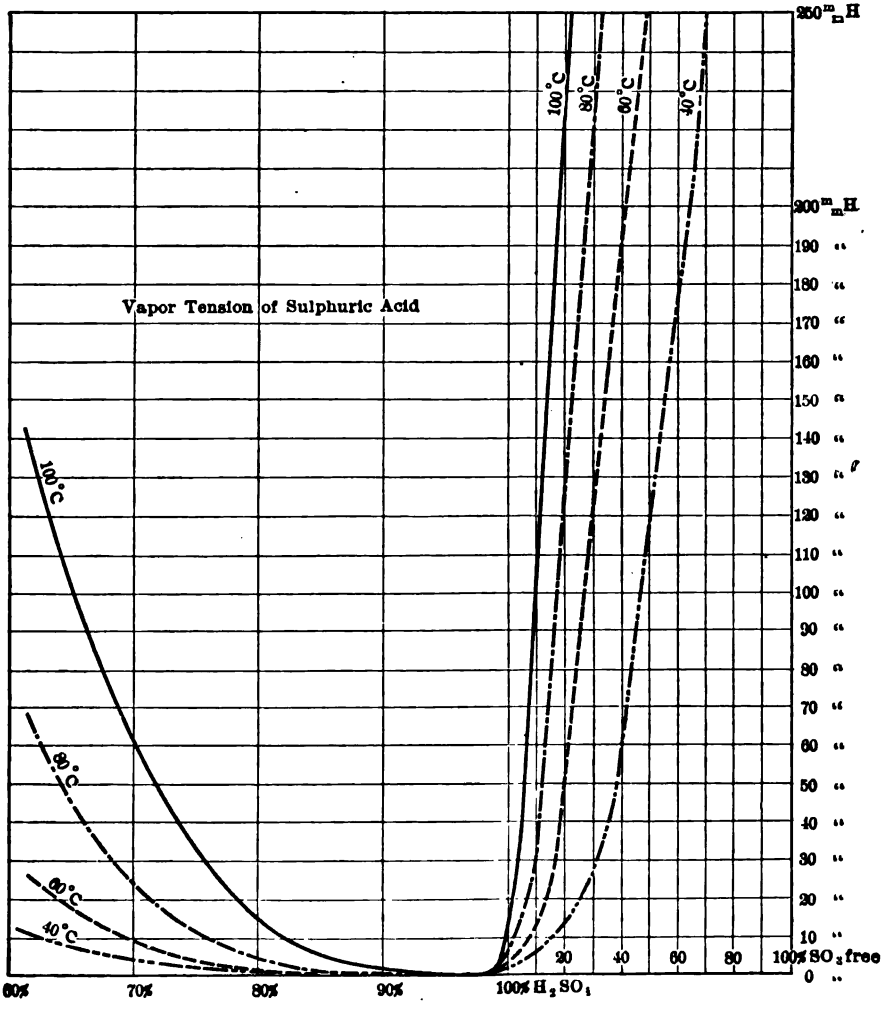
[41] See also Regnault *Annalen d. Chim.*, 15-179, and *Lunge's Handbuch*, 1893, 122-123.

Vapor Tension.—Method: The vapor pressures of watery sulphuric acid were found in the ordinary manner by measuring the depression of the mercury

DEPRESSIONS IN MM. QUICKSILVER.

H_2SO_4.	20°.	40°.	60°.	80°.	100°.
%	Mm.	Mm.	Mm.	Mm.	Mm.
61·7	3	10	25	68	143
70·9	2	3	8	22	57
81·4	1	1	1·5	3	10
89·28					
93·8					
96·26	0	0	0	0	0
97·76					
98·56					

column of barometer height at various constant temperatures. With fuming acids this method cannot be used, the free sulphuric trioxide attacking the mer-

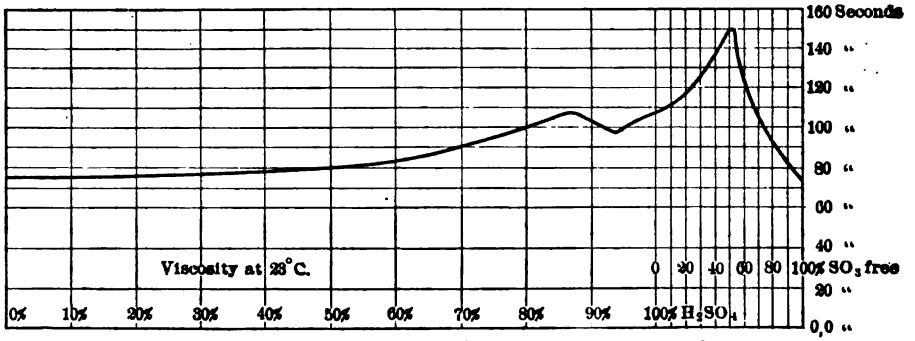


cury. The measuring was therefore done in an iron apparatus by means of a manometer which method is probably sufficiently accurate for practical purposes.

VAPOR TENSION OF VARIOUS FUMING SULPHURIC ACIDS (75% VOLUME OF ACID AND 25% VOLUME OF AIR).

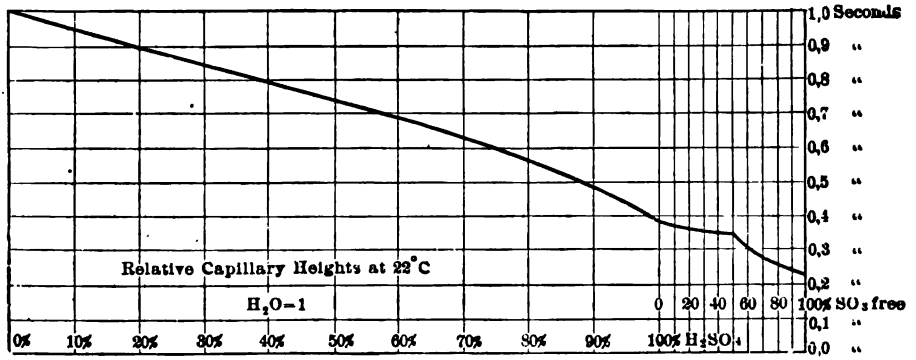
Temperature	Vapor. Tension of Acid. 30%.	Vapor. Tension of Acid. 40%.	Vapor. Tension of Acid. 50%.	Vapor. Tension of Acid. 60%.	Vapor. Tension of Acid. 70%.	Vapor. Tension of Acid. 80%.	Vapor. Tension of Acid. 100%.
	Atmospheres	Atmospheres	Atmospheres	Atmospheres	Atmospheres	Atmospheres	Atmos.
35	.....	.....	.....	.....	.....	0·150	0·400
40	.....	0·075	.....	0·225	0·375	0·500	0·650
45	0·050	0·125	.....	0·350	0·575	0·650	0·875
50	0·100	0·175	0·350	0·525	0·775	0·875	1·200
55	0·140	0·225	0·450	0·675	1·025	1·200	1·600
60	0·200	0·275	0·550	0·825	1·400	1·500	1·850
65	0·225	0·350	0·700	1·025	1·650	1·900	2 250
70	0·275	0·400	0·825	1·275	2·050	2·300	2·725
75	0·340	0·475	1·000	1·570	2·525	2·800	3·300
80	0·400	0·575	1·150	1·850	3·100	3·500	4·000
85	0·450	0·675	1·400	2·150	3·700	4·175	4·900
90	0·530	0·825	1·700	2·575	4·400	5·050	5·900
95	0·625	0·950	2·050	3·150	5·200	6·000	.....
100	0·730	1·100	2·400	3·700	6·000	.....	.....

Viscosity.—Method: The acid was drawn up to the work in a cylindrical glass tube containing 320 c.c. narrowed at the top and having a diameter of 28 mm. The acid was allowed to flow out through a short opening about 1·75 mm. in diameter. The time taken for equal volumes to flow out was



measured by means of a watch registering quarter seconds. The temperature was almost constant at 23°C. during these experiments.

Capillarity.—The rise in capillary tubes was measured in flat capillary tubing used for thermometers, carefully cleaned and dried for each determination; the



heights were measured in dry tubes and also in tubes previously moistened with the same acid that was to be tried. In most cases these determinations agreed

with each other. Where differences existed the height for the moistened capillary tube was taken as the correct one. The tube had a lens-shaped cross section.

CAPILLARY ATTRACTION OF ORDINARY AND FUMING SULPHURIC ACIDS.

Capillary Attraction at 22° C.					Velocity of Outflow of Ordinary and Fuming Sulphuric Acid	
H_2SO_4. Water.	SO_3.	Free SO_3.	Unger Auf $H_2O=100$.	Determined.	Determined.	Calculated to $H_2O=100$.
%	%	%		Mm.	Seconds.	
.....	.....	.....	100	85	75·5	100
9·5	.....	.....	95 29	81	75·5	100
18·7	.....	.....	90·58	77	75·75	100·3
27·8	.....	.....	85·88	73	76·5	101 3
37·3	.....	.....	82·35	70	77·5	102·6
46·4	.....	.....	76·47	65	80·0	106·0
55·9	.....	.....	71·76	61	82·5	109·3
65·2	.....	.....	65·88	56	86·5	114·6
74·4	.....	.....	61·17	52	95·0	125·8
81·5	.....	.....	55·88	47·5	104·5	138·4
86·1	.....	.....	51·76	44	107·0	141·7
86·8	.....	.....	51·17	43·5	107·25	142·0
89·2	.....	.....	49·41	42	105·5	139·7
93·8	.....	.....	44·70	38	98·0	129·8
96·3	.....	.....	42·35	36	103·5	137·1
97·7	.....	.....	40·58	34·5	105·5	139·7
98·6	.....	.....	40·00	34	106·0	140·4
100·3	81·8	0·9	38·23	32·5	110·0	145·7
100·9	82·4	4·2	38·23	32·5	111·0	147·0
101·9	83·2	8·5	37·64	32	111·5	147·7
103·4	84·4	15·1	37·64	32	114·0	151·0
104·4	85·2	19·4	36·47	31	117·5	155·6
106·8	87·2	30·3	36·46	31	126·0	166·9
108·8	88·8	39·0	35·29	30	130·0	170·8
111·2	90·8	49·9	35·29	30	150·0	198·7
113·2	92·4	58·6	32·94	28	145·0	192·0
115·6	94·4	69·5	29·41	25	109·5	145·0
118·1	96·4	80·4	25·88	22	95·0	125·8
120·1	98·0	89·1	24·70	21	83·0	109·9
122·5	99·8	98·9	23·52	20	76·0	100·7

A mercury thread 22 mm. in length weighed 0·0366 g., one 52·5 mm. in length, 0·087 g., so that a length of 1 mm. corresponded to 0·00166 g. of mercury or a volume of 0·122 c.mm.

TABLE TO CALCULATE THE FREE SO_3 CONTENT OF FUMING SULPHURIC ACID FROM THE TOTAL SO_3 PRESENT.

SO_3.		SO_3.		SO_3.		SO_3.		SO_3.		SO_3.		SO_3.	
Total.	Free.	Total.	Free.	Total.	Free.	Total.	Free.	Total.	Free.	Total.	Free.	Total	Free.
81·63	0·0	84·8	14·5	87·0	29·2	89·6	43·4	92·2	57·5	94·8	71·7	97·4	85·8
81·7	0·4	84·4	15·1	87·1	29 8	89·7	43·9	92·3	58·1	94·9	72·2	97·5	86·4
81·8	0·9	84·5	15·6	87·2	30·3	89·8	44·5	92·4	58·6	95·0	72·8	97·6	86·9
81·9	1·5	84·6	16·2	87·3	30·9	89·9	45·0	92·5	59.2	95·1	73·3	97·7	87·5
82·0	2·0	84·7	16·7	87·4	31·4	90·0	45·6	92·6	59·7	95·2	73·9	97·8	88·0
82·1	2·6	84·8	17·2	87·5	31 9	90·1	46·1	92·7	60·3	95·3	74·4	97·9	88·6
82·2	3·1	84·9	17·8	87·6	32·5	90·2	46·6	92·8	60·8	95·4	75·0	98·0	89·1
82·3	3·6	85·0	18·3	87·7	33·0	90·3	47·2	92·9	61·3	95·5	75·5	98·1	89·7
82·4	4·2	85·1	18·9	87·8	33·6	90·4	47·7	93·0	61·9	95·6	76·1	48·2	90·2
82·5	4·7	85·2	19·4	87·9	34·1	90·5	48·3	93·1	62·4	95·7	76·6	98·3	90·7
82·6	5·3	85·3	20·0	88·0	34·7	90·6	48·8	93·2	63·0	95·8	77·1	97·4	91 3
82·7	5·8	85·4	20·5	88·1	35·2	90·7	49·4	93·3	63·5	95·9	77·7	98·5	91·8
82·8	6·4	85·5	21·0	88·2	35·8	90·8	49·9	93·4	64·1	96·0	78·3	98·6	92·4
82·9	6·9	85·6	21·6	88·3	36·3	90·9	50·5	93·5	64·6	96·1	78·8	98·7	92·9
83·0	9·5	85·7	22·2	88·4	36·8	91·0	51·0	93·6	65·2	96·2	79·3	98 8	93·5
83·1	8·0	85·8	22·7	88·5	37·4	91·1	51·6	93·7	65·7	96·3	79·9	98·9	94·0
83·2	8·5	85·9	23·2	88·6	37·9	91·2	52·1	93·8	66·2	96·4	80·4	99·0	94·6
83·3	9·1	86·0	23·8	88·7	38·5	91·3	52·6	93·9	66·8	96·5	81·0	99·1	95·1
83·4	9·6	86·1	24·3	88·8	39.0	91·4	53·2	94·0	67·3	96·6	81·5	99·2	95·6
83·5	10·2	86·2	24·9	88·9	39·6	91·5	53·7	94·1	67·9	96·7	82·0	99·3	96·2
83·6	10·7	86·3	25·4	89·0	40·1	91·6	54·3	94·2	68·4	96·8	82·6	99·4	96·7
83·7	11·3	86·4	26·0	89·1	40·6	91·7	54·8	94·3	69·0	96·9	83·1	99·5	97·3
83·8	11·8	86·5	26·5	89·2	41·2	91·8	55·4	94·4	69·5	97·0	83.7	99·6	97·8
83·9	12·3	86·6	27·0	89·3	41·7	91·9	55·9	94·5	70·1	97·1	84·2	99·7	98·4
84·0	12·9	86·7	27·6	89·4	42·3	92·0	56·4	94·6	70·6	97·2	84·8	99·8	98·9
84·1	13·4	86·8	28·1	89·5	42·8	92·1	57·0	94·7	71·2	97·3	85·3	99 9	99·5
84·2	14·0	86·9	28·7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TALC AND SOAPSTONE.

THE production of fibrous talc in 1901 was 69,200 short tons, valued at $483,600, showing a large increase compared with the figures for the previous year. The production of common talc during 1901 is included with soapstone; the output in 1900 was 7,770 short tons ($60,217). The output of soapstone amounted to 28,643 short tons ($424,888), against 18,956 tons ($189,560) for the preceding year.

PRODUCTION AND IMPORTS OF FIBROUS TALC AND SOAPSTONE IN THE UNITED STATES. (IN TONS OF 2,000 LB.)

Year.	Production.									Imports. (b)		
	Fibrous Talc.			Common Talc.			Soapstone.			Tons.	Value.	Per Ton
	Tons.	Value.	Per Ton	Tons.	Value.	Per Ton	Tons.	Value. (a)	Per Ton			
1897....	52,836	$283,685	$5·37	10,164	$90,908	$8·94	16,904	$169,040	$10·00	799	$8,423	$10·54
1898....	54,807	285,759	5·21	9,112	78,645	8·63	18,862	158,635	8·41	445	5,526	10·70
1899....	57,120	272,595	4·77	6,671	51,763	7·71	20,011	189,504	9·47	254	3,534	13·91
1900....	45,000	236,250	5·25	7,770	60,217	7 75	18,956	189,560	10·00	79	1,070	13·50
1901....	69,200	483,600	6·99	(c)	(c)	(c)	d28,643	424,888	14·83	2,386	27,015	11·32

(a) In reporting the value of their output of soapstone producers generally give the figures for the finished articles which they make. Since a varying proportion of labor enters into these, such figures are apt to be misleading. Few producers are able to name a value of the crude stone, or roughly dressed blocks. We have therefore valued the material arbitrarily at this stage at $10 per ton, except in 1898 when a large production of inferior stone reduced the average. The value in 1899 is that reported by the producers. (b) Talc, ground, powdered or prepared. (c) Included with soapstone. (d) Includes common talc.

Fibrous Talc.—The larger part of the fibrous talc production continues to come from St. Lawrence County, N. Y., and its use for incorporation with paper pulp is increasing. A consolidation of a number of small properties will in all probability develop an increased production during 1902. Fibrous talc also is largely used for paint and plaster for walls.

Talc and Soapstone.—The bulk of the Virginia output of soapstone is manufactured into articles of utility by the producers. Considerable amounts of the North Carolina talc found its ultimate usage in paper making. There was a large increase in the output of pyrophyllite soapstone from Moore County, N. C. during 1901. The greater part of the talc which is used for the manufacture of pencils, and of coal and acetylene gas tips, is obtained from Swain County, N. C. This variety of talc commands the highest prices of any in this country. There appears to be an increasing demand in the United States for talc suitable for grinding to flour.

TIN.

As in previous years, there was no production of tin in the United States during 1901. Some experimental work was carried on in the Black Hills, South Dakota, and at one prospect near Oreville five tons of selected ore was concentrated to 1,361 lb. of tin oxide (cassiterite) which contained gold to the value of $10. The total value of the product was reported to be $1,525. The process consisted of heap roasting with wood fuel, dry crushing to 60-mesh size and concentration on Wilfley tables. Several hundred tons of low-grade ores have been mined for exploitation purposes, but as yet the tin industry in the Black Hills has not been placed on a commercial basis.

The separation of tin from tin-plate scrap was continued during 1901 by the Vulcan Detinning Co., which early in 1902 was capitalized at $3,500,000 to acquire the Vulcan Metal Refining Co., of Sewaren, N. J., and the Vulcan Western Co., of Streator, Ill., the production of both plants during 1901 being about 500 tons of pig tin. The production of The Ammonia Co., of Philadelphia, from scrap tin during 1901 was about 75 tons of pig, which was chiefly converted into chloride of tin. The production of the Johnston & Jennings Co., of Cleveland and Chicago, from scrap tin was about 250 tons, partly made into pig and partly into tin oxide.

IMPORTS OF TIN INTO THE UNITED STATES.

Year.	Pounds.	Value.	Year.	Pounds.	Value.	Year.	Pounds.	Value.
1896.....	44,639,324	$5,848,933	1898.....	62,748,399	$8,770,221	1900.....	69,989,502	$19,458,586
1897.....	55,172,571	7,415,933	1899.....	71,248,407	16,746,107	1901.....	74,560,487	19,024,761

THE PRINCIPAL TIN SUPPLIES OF THE WORLD. (*a*) (IN LONG TONS.)

	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.
English production.....	8,328	6,648	4,887	4,458	4,648	4,013	4,268	4,125
Straits shipments to Europe and America...	45,640	47,840	47,180	41,700	43,350	44,460	46,070	49,925
Australian shipments to Europe and America	5,824	4,902	4,320	3,466	2,420	3,337	3,178	3,345
Banka sales in Holland.....	5,626	6,221	6,785	8,900	9,038	9,066	11,820	14,978
Sales of Singkep in Holland.....	261	644	889	800	*Nil.*	*Nil.*	*Nil.*	*Nil.*
Billiton sales in Java and Holland.....	4,735	4,530	5,040	5,100	5,342	5,057	5,820	4,387
Bolivian arrivals on Continent.....	.....	.....	210	1,308	1,000	813	1,900	9,670
Bolivian arrivals in England.....	3,482	4,097	3,829	4,208	3,464	3,940	5,097	
Straits shipments to India and China.....	4,655	4,674	6,118	3,214	2,551	1,484	1,785	2,650
Totals in long tons.....	78,551	79,655	79,108	73,189	71,763	72,557	79,878	89,080
Totals in metric tons.....	79,808	80,930	80,374	74,309	72,911	73,718	81,156	90,505

(*a*) This table is based on the statistics compiled by William Sargant & Co., and Ricard & Freiwald, but the figures of English production are taken from the British blue-book. This table does not include the production of Germany, Austria, Spain, Portugal, and various other countries.

PRODUCTION OF TIN IN THE WORLD. (*n*)

Year	Australia. (*a*)			Austria. (*b*)			Banka and Billiton. (*c*)	Bolivia. (*d*)	England. (*e*)			Germany. (*f*)		
	Met. Tons.	Value. (*o*)	Per M Ton.	Met. Tons.	Value. (*o*)	Per M Ton.	Metric Tons.	Metric Tons.	Met. Tons.	Value. (*o*)	Per M Ton.	Met. Tons.	Value. (*o*)	Per M Ton.
1896.	1,737	$496,060	$286	54	$18,266	$341	11,963	4,104	4,915	$1,538,390	$313	826	$238,017	$288
1897.	1,159	350,640	303	48	16,806	350	14,224	5,594	4,524	1,456,680	322	929	287,829	310
1898.	908	302,825	333	48	19,074	397	14,610	4,535	4,722	1,729,060	366	993	372,252	375
1899.	835	490,690	587	41	24,639	601	14,496	8,012	4,077	2,540,470	623	1,481	870,750	590
1900.	915	600,160	656	40	28,066	702	18,284	10,245	4,336	(*p*)	(*p*)	2,081	1,332,750	651

Year.	Japan. (*g*)	Mexico. (*h*)	Portugal. (*i*)	Russia. (*j*)			Singkep. (*k*)	Straits Settlements. (*l*)	Tasmania. (*m*)			Total Met. Tons.
	Met. Tons	Met. Tons.	Met. Tons.	Met. Tons.	Value (*o*)	Per M Ton.	Met. Tons.	Met. Tons.	Met. Tons.	Value. (*o*)	Per M Ton.	
1896	50	5	6	2	$476	$238	852	53,964	4,759	$1,327,369	$290	83,237
1897	47	1	1	2	476	238	813	45,232	3,484	749,970	302	75,409
1898	43	*Nil.*	*Nil.*	(*p*)	(*p*)	(*p*)	685	46,635	2,038	705,810	346	75,211
1899	18	*Nil.*	*Nil.*	(*p*)	(*p*)	(*p*)	678	46,679	2,275	1,355,433	596	78,592
1900	12	*Nil.*	*Nil.*	(*p*)	(*p*)	(*p*)	575	46,795	1,852	(*p*)	(*p*)	83,015

(*a*) From *Report of Secretary of Mines and Agriculture of New South Wales*, which is the only Australian colony that produces metallic tin. Tin ore is also exported from New South Wales. Tin ore is produced in Victoria, Queensland, South Australia, and Western Australia, but its metal contents are reported in the productions of other countries.

(*b*) From the *Statistisches Jahrbuch des K. K. Ackerbau-Ministeriums*. The tin production of Austria is derived partly from domestic ores, and partly from Bolivian ores and impure tin from the East imported for refining.

(*c*) Total sales in Holland and Java as reported by William Sargant & Co.

(*d*) Exports of tin and tin in ore from Bolivia to England and the Continent. Some of this tin may be produced in Peru. It is all exported through Peruvian and Chilean ports.

(*e*) From *Mineral Statistics of the United Kingdom*. These figures give the amount of tin estimated to be obtainable in smelting the ore of domestic production. They differ considerably from the figures used by William Sargant & Co., which are possibly obtained directly from the smelters.

(*f*) From *Vierteljahrs und Monatshefte zur Statistik des Deutschen Reichs*. By far the larger part of this production is from Bolivian ores.

(*g*) From the *Resume Statisque de l'Empire du Japon*.

(*h*) According to export returns. Small amounts produced by natives for domestic consumption are not included.

(*i*) From official returns furnished by the Portuguese Government. The figures for 1896 include tin ore.

(*j*) From Russian official reports.

(*k*) The figures represent sales in Holland, reported by De Mouchy & Havelaar and W. Sargant & Co.

(*l*) Shipments from the Straits to Europe and America, as reported by William Sargant & Co., and to India and China by Boustead & Co., except the figure for 1896, which is taken from the *Report of the Governor of the Straits Settlements*.

(*m*) From *Report of the Secretary of Mines*.

(*n*) It will be observed that this table differs from the statistics usually referred to for the world's production of tin, namely, those of William Sargant & Co., and of the *Metallurgischegesellschaft Frankfurt-am-Main*. This is because (1) they reckon Australian shipments to Europe and America, instead of the Australian production, whereby a good deal of Australian tin consumed at home is not included; (2) shipments from the Straits to India and China and the production of several minor countries are not included. A small amount of tin produced in Spain is necessarily omitted, owing to the absence of statistics for that country.

(*o*) In cases where the statistics in the above table have been taken from official sources, wherein values of product have been stated, a calculation of unit values has been made. This developed some amazing differences, which are undoubtedly due to making value calculations at different stages of the product; i.e., more or less cost of carriage is included.

(*p*) Statistics not yet published.

Alaska.—A discovery of stream tin on Buhner creek, 10 miles east of Cape Prince of Wales, in the York gold field has been made. Two to three feet of gravel overlie the bed-rock which consists of arenaceous schists, often graphitic and graphitic slates. The stream tin is concentrated on the bed-rock with small amounts of magnetite, limonite, pyrite, fluorite, garnets and gold. A second locality is on the Anaovik river, into which Buhner creek flows, and is about 0·5 miles from the latter deposit. Recoveries of from 150 to 200 lb. of cassiterite per cu. yd. are reported.

AUSTRALASIA.—*New South Wales.*—The total value of the tin produced in New South Wales in 1901 was £77,315, as compared with £142,724 in 1900, and £90,482 in 1899. The tin mining suffered greatly from drought in 1901, and to a less extent by the lower prices for the metal. The number of men employed on the alluvial and other deposits during 1901 was £1,428. The principal lode mine continues to be the Ottery, in the Emmaville district.

STOCKS OF TIN IN ENGLAND, AMERICA AND HOLLAND. (*a*) (IN LONG TONS.)

	1894.	1895.	1896.	1897.	1898.	1899.	1900.
Stocks, December 31—							
Stock of foreign in London	8,985	13,539	18,097	15,146	8,110	5,486	4,286
Foreign landing in London	1,189	1,025	1,174	673	165	1,212	1,997
Straits afloat for London, including wire advices	3,778	2,825	2,792	2,500	1,050	2,900	3,835
Australian afloat for London, including wire advices	650	825	525	600	400	450	350
Banka on warrants in Holland	1,006	1,154	1,616	2,877	2,228	1,160	857
Billiton in Holland	1,632	1,507	1,638	1,328	1,086	470	330
Billiton afloat for Holland	1,129	1,097	1,742	1,193	1,322	1,050	350
Straits stock in Holland	767	277	789	377	454	100	60
Straits afloat for Holland	.....	.....	950	100	215	.....	.....
Straits afloat for Continent	.....	.....	650	600	560	450	590
Bolivian in Liverpool	494	492	250	710	300	550	495
Total stocks	19,630	22,741	30,223	26,104	15,840	13,828	12,430
Estimated stock in America and quantity floating	3,820	6,823	3,925	4,500	4,300	2,500	2,600
Grand totals	23,450	29,564	34,148	30,604	20,140	16,328	15,030
Trading Co.'s res'v's of unsold Banka stock in Holland	5,770	6,140	5,953	4,333	3,213	4,353	5,347

(*a*) From the annual metal circular of William Sargant & Co.

CONSUMPTION OF TIN IN ENGLAND, AMERICA AND HOLLAND. (*a*) (IN LONG TONS.) (*b*)

	1895.	1896.	1897.	1898.	1899.	1900.
Consumption—						
Deliveries from London after deducting all shipments to America	17,223	19,015	17,118	15,472	13,519	16,061
Deliveries from Holland after deducting exports to London and America	9,029	10,150	11,680	12,130	13,094	14,416
English consumed at home	988	5,000	4,400	4,600	4,400	3,500
Exports of English, minus quantity shipped to America	5,530					
American consumption of all sorts	22,500	29,500	22,500	28,500	31,500	31,100
Billiton sent to other ports than Holland	1,582	1,603	1,370	2,120	1,980	2,400
Straits direct to Continent, less re-exports to America and England	7,622	11,400	9,170	12,740	6,470	5,400
Bolivian delivered from Liverpool	4,099	4,071	3,338	3,374	3,690	5,028
Bolivian delivered from Continent	.....	210	1,208	1,000	813	1,900
Totals	68,522	71,949	71,284	80,436	75,416	79,869

(*a*) From the annual metal circular of William Sargent & Sons. (*b*) Not classified for 1901.

Northern Territory.—Lode and stream tin are found in workable quantities at Mount Todd and Horseshoe creek. Several hundred weight which averaged well in value were shipped out to Sydney early in 1902 and a number of parties are prospecting. The stream tin runs from pieces the size of shot up to 7 to 8 lb. in weight.

Queensland.—The value of the production of tin in Queensland during 1901 was £93,723, as compared with £74,041 (1,141 metric tons of dressed tin ore) in 1900. Early in 1902 the main shaft of the Great Northern Freehold Tin Mine, at Heberton, was completed, the latter part of the sinking passing through very favorable tin formations. The Smith's creek tin mine, seven miles from Mount Garnet, is said to have a lode 30 ft. thick yielding 30% of 70% ore on its 24-acre lease. A company capitalized at £7,200 has been organized to operate

the property. The prospecting of the New England mine on Smith's creek, near Mount Garnet, appears to have been of a favorable character, specimens of the 40 to 50 lb. weight of stream tin 70% pure having been obtained. In the latter half of 1901 the Vulcan tin mine, at Irvinebank, crushed 2,097 tons of stone for a yield of 181 tons of black tin, valued at £6,793, and £1,650 was declared in dividends. A new power battery has been erected, which is expected to increase the output.

South Australia.—The production of tin ore in South Australia was 17 metric tons, valued at £774 in 1900, as compared with 2 statute tons, valued at £180 in 1899.

Tasmania.—The output of tin ore was less in 1901 than in the preceding year. This unexpected result being due principally to the poorer quality of the ore raised from the Mt. Bischoff mines, the most productive in the State. The mining in the St. Helens district is principally alluvial, among the companies operating being the Royal Ruby Tin Mining Co., Thureau's Deep Lead Tin Mining Co., the Upper Ruby, the Rose Tin Co., and several smaller companies. The Scamander Tin & Gold Mining Co. was recently organized to treat by hydraulicking the extensive alluvial flats on the banks of the Scamander river for the recovery of gold and tin. The Briseis mine, on the Ringarooma river, owned by the Venture Corporation, has constructed a water supply race 3 ft. deep by 6 ft. wide, by 30 miles in length, to insure a water supply during the dry season. By means of this head of water the basalt overburden is removed at a cost of 2d. per cu. yd., and the tin drift somewhat cheaper. The amount of tin ore recovered from the drift is estimated at about 0·8%, and an output of from 150 to 200 tons per month is anticipated. Across the Ringarooma river the Ringarooma Tin Mining Co. has installed a 1,000-H.P. pumping plant which has been for some time hydraulicking the overburden with good prospects of success. The Pioneer Co. works a flat deposit by means of a 250-H.P. engine, at a cost of £10 per H.P., and sand-pump placed on a flat boat, which is floated into position, and the water then pumped out until the boat rests on the bottom. The drift in this mine is first sluiced down by water under several hundred feet of pressure, and then elevated by a pump nearly 80 ft. to a tail race; 1·5 cu. yd. of drift per minute are raised, using about 40 cu. ft. of water, and over 40 tons of tin ore, valued at £70 per ton are secured per month. The Anchor Tin Mine, Ltd., has had under construction during 1901 a 39-mile water race, which is to be extended to the South George river, tapping the Waratah creek and the North George river on the way. The cost of this improvement is expected to be about £15,000 when completed about June, 1902. The ore is of very low grade, but apparently inexhaustible in quantity. It is anticipated that the entire mill of 100 stamps will be run by water power when the same is available. Early in 1902 a plan for the reorganization of the company was proposed. The issues of first debentures aggregating £15,000 at 7%, and the second debentures aggregating £10,000 at 10%, were consolidated into first debentures at 7·5% per annum. The new corporation of the same name is to be capitalized at £120,000, against the previous capitalization of £150,000, and a call of 5s. per share, which will realize £28,500, was issued, the which, after paying outstanding debts, was esti-

mated to provide £14,000 for working capital. The percentage of tin extracted since 1898 has ranged from 0·32 to 0·38%. Tests by the Government Assayer of the tin ore from the deposits on Schouten Main yielded by assay from 1·2 to 4% tin, the ore occurring in tin granite. Tests made of the alluvial from the Schouten Main Mining & Dredging Co.'s claims averaged 2 lb. tin or 2·86 lb. tin ore (at 70%) per cu. yd. The deposits would pay with careful management. The Mt. Bischoff Mining Co. during the six months ending December 31, 1901, smelted 1,416 tons of concentrates yielding 980 tons of tin; of this 633 tons, yielding 440 tons of tin was smelted on account of the company. The accounts at the end of the year showed a credit balance of $234,015 after distributing $200,695 in dividends and writing off various amounts at the rate of 20% for depreciation. The average percentage of concentrates obtained from the ore was 1·312%, and the total output from the foundation of the company up to December 31, 1901, was 59,656 tons.

Western Australia.—The total quantity of black tin mined during 1901 amounted to 734 tons, valued at £40,000, against 824 tons, valued at £56,702 in 1900. The output of the Greenbushes mining district during 1901 was 321 tons, valued at £18,852, while that of the Marble Bar district was 413 tons, valued at £21,148.

Bolivia.—One of the most important tin mining districts in Bolivia is that of Huanuni, where the ore occurs in numerous veins and lodes traversing the granitic country rock. Most of the veins are very rich in ore, but considerable difficulty is experienced in extracting the tin on account of the extreme hardness of the veins and the adjoining rocks. A considerable amount of tin pyrites is found, from which the tin is extracted by calcination and subsequent grinding and washing. About 10 miles south of the Huanuni are the Challa Apacheta mines, which are opened on several lodes, one of which is remarkable for its extent, the veins being from 25 to 30 ft. in width. The tin ore is found here in granular form interspersed through an argillaceous matrix, which doubtless represents the weathered product of original vein materials. In the Ouroro district, which exported 8,177 metric tons of tin ore in 1900, is the Avecayo deposit, while to the east of this district are the mines of Berenguela, both of which yield considerable quantities of ore. The exports of Bolivian tin from Antofagasta, Chile, during 1900 were 8,721 long tons of small tin bars, valued at £195,271; 2·75 long tons of tin, valued at £520; and 76 long tons of tin minerals, valued at £370.

France.—Small veins carrying cassiterite are known to occur near Vaulry, on the Limoges-Bellac railway, and have been worked from time to time without however attaining the position of an established enterprise. Recently a new company—the Société des Mines de Vaulry et Cieux, secured a concession of alluvial ground near by from which it is producing some ore. The method of extraction includes washing of the gravels and concentration on Wilfley tables.

Malay Peninsula.—The total output of tin for 1901 was 46,984 long tons, against 42,442 long tons in 1900. The increased price of tin during all of 1900 and the early part of 1901 stimulated production in fields formerly abandoned as too low grade, and labor was plenty during both years. The production of the

individual Federated Malay States for the years 1900 and 1901 will be found in the subjoined table:—

Malay States.	1900.		1901.	
	Long Tons.	Metric Tons.	Long Tons.	Metric Tons.
Perak	21,166	21,506	22,920	23,287
Selangor	16,041	16,298	18,018	18,306
Negri-Sembilan	4,300	4,369	4,479	4,551
Pahang	935	950	1,567	1,592
Totals	42,442	43,123	46,984	47,736

The report for 1901 of the Pahang Kabang, Ltd., shows that while a profit of £786 was made on total receipts of £3,020, the average yield per ton of gravel or black tin was but 46·7 lb., or about the same as the recoveries at Dolcoath, Cornwall.

Late in 1901 the Tronoh Mines, Ltd., capitalized at £160,000 was registered to work mines at Tronoh. A full equipment of modern mining machinery will be installed.

A recent examination of the tin deposits of Johore results in the discovery of large tin fields in the vicinity of Ayer Putch. While the surface tin is difficult to save by Chinese methods, owing to its fineness and association with iron, the coarser gravels near bed-rock are said to yield large recoveries.

United Kingdom.—The Dolcoath Mine, Ltd., during the second semester of 1901 earned a net profit of £16,274, against £16,902 for the previous half year. A call of 2s. 6d. was made on the partly paid shares, which increased the capital stock by £2,157 15s. A number of improvements were made in the mining and milling plants, which it is thought will increase the output of tin and at the same time reduce the working costs. From the total cash surplus of £17,024 10s. a dividend of £7,481 6s. was paid the shareholders, leaving £8,932 3s. to be written off capital account and £611 1s. to be carried forward. Its statistics of production for several years are given in the subjoined table:—

Six Months.	Tin Ore Crushed.	Black Tin Sold.	Product per Ton of Ore.	Average Value per Ton of Ore.	Average Price per Ton of Black Tin.	Amount Realized.
	Tons.	T. c. q. lb.	Lb.	£ s. d.	£ s. d.	£ s. d.
June 30, 1897	35,879	1,021 17 0 22	63·79	1 1 7·27	37 18 7	38,760 7 2
December 31, 1897	37,686	1,073 2 1 9	63·78	1 1 6·78	37 17 4	40,636 19 8
June 30, 1898	38,089	1,140 7 2 22	67·07	1 3 8·94	39 16 4	45,221 15 1
December 31, 1898	40,608	1,162 0 0 0	64·10	1 6 10·09	46 18 0	54,497 6 3
June 30, 1899	41,101	1,037 19 1 23	56·57	1 13 8·21	66 12 7	69,222 12 0
December 31, 1899	41,639	1,040 18 1 10	56·00	1 19 8·39	79 7 11	82,851 16 0
June 30, 1900	45,102	1,043 9 0 0	51·80	1 28 3·57	82 15 4	86,364 18 10
December 31, 1900	43,254	960 19 1 21	49·76	1 15 11·4	80 18 2	77,750 14 4
June 30, 1901	47,603	1,001 18 1 5	47·14	1 10 8·69	72 19 10	73,182 0 11
December 31, 1901	48,975	1,033 18 1 18	47·28	1 8 10·35	68 7 6	70,676 2 6

THE TIN MARKETS IN 1901.

New York.—The tin market maintained its reputation as a center for speculative trading, and the prices, as in previous years, showed extensive fluctuations which were not traceable to any corresponding change in the statistics. In fact the supplies of the metal apparently exerted little influence on quotations in times of heavy buying or depression from outside sources. To a large degree the market

freed itself from the influence of silver prices. Consumption throughout the year was heavy, with only short interruptions on this side of the Atlantic, our market very often moving entirely independent of that of London. Futures could at nearly all times be bought at a discount. On the other hand, the scarcity of labor caused by the Chinese war, which made itself felt last year to the detriment of the production in the far East, was followed by an abundant supply.

The year opened rather dull, spot tin selling at about 26·50c., and consumers and speculators not taking much interest in the article. By the middle of March prices had declined to 25·5c. Business then became more brisk, and stimulated by speculative buying the market advanced to 28·50c., which was the closing quotation at the end of May. It kept steady throughout the month of June at about that figure. Somewhat later, the steamer *Asturia* with 750 tons of tin aboard foundered, and the London market was practically cornered, spot tin over there at one time selling at £140, and three months at £123 15s., a backwardation of nearly £17. A sharp decline abroad carried prices down also in this country, and during August spot tin could again be bought at 26·5c.

During September, the strike at the mills of the United States Steel Corporation exercised a depressing influence on the market. In view of the heavy fluctuations in London and the large backwardation manufacturers allowed their stocks to run down and confined their purchases to their immediate requirements. With spot tin ruling at a premium of from 1 to 2c., quotations nevertheless steadily declined until 24·5c. was reached the beginning of November. About the middle of the month, the lethargy which had prevailed for such a long time gave way to considerable activity. The steel strike came to an end, and while the consumption apparently was very large, the available supply in sight was quite small. This caused prices to advance by leaps and bounds, and during the last few days of November it developed that the market to all intents and purposes was cornered. Some belated bears had to pay 33 and 35c. to cover their commitments. These extraordinary conditions were soon followed by a sharp reaction. The East was selling freely at the high values which had been established; several overdue steamers arrived with large quantities of tin aboard, and in sympathy with the heavy decline in copper, prices suddenly broke to 25c. About the middle of December, the failure of one of the most prominent operators on the London Metal Exchange was announced, and another heavy decline set in, spot tin selling at 23c. Consumers bought freely at this figure, and the year closed with spot tin selling at 23·37@23·75c. and futures at 23@23·25c.

AVERAGE MONTHLY PRICES OF TIN IN NEW YORK.

Year.	Jan.	Feb.	Mar.	April	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.
1897	13·44	13·59	13·43	13·34	13·44	13·77	13·89	13·80	13·98	13·88	13·79	13·71	13·67
1898	13·87	14·08	14·38	14·60	14·52	15·22	15·60	16·23	16·03	17·42	18·20	18·80	15·70
1899	22·48	24·20	23·82	24 98	25·76	25·85	29·63	31·53	32·74	31·99	28·51	25·88	25·12
1900	27·07	30·58	32·90	30·90	29·37	30·50	33·10	31·28	29·42	28·54	28·25	26·94	29·90
1901	26·51	26·68	26·03	25·93	27·12	28·60	27·85	26·78	25·31	26·62	26·67	24·36	26·54

London.—At the commencement of 1901, the statistics showed a decrease, ex-

cluding American, of 2,132 tons, and a total visible supply of about 23,000 tons. In the latter part of December, 1900, the price rose to £124 in anticipation of large American purchases, but buying declined toward the close of the year, and January opened with the market at £122 10s. for all positions, but prices gradually dropped to about £118. Toward the close of the month, however, business was fairly active, and £123 17s. 6d. was touched for close dates. Forward tin was freely offered, the month closed at £121 5s. cash and a backwardation of £4 on three months. Statistics at the beginning of February showed a further decrease in European stocks of 396 tons, but supplies during January had largely exceeded the demand, and the total tonnage in sight was increased by 1,600 tons. On the strength of the above European figures the month opened with prices at £123 for early deliveries; the backwardation on forward increasing to about £5. Toward the middle of the month prices declined, and the closing quotations were £121 cash and £115 12s. 6d. three months. March opened with a decrease of 786 tons in European stocks and a further addition to the total visible supply. Heavy arrivals in London eased spot prices, and values gradually sank to £118 10s. for early dates, £115 for end of April and £113 7s. 6d. for three months. The end of the month saw prices at £115 5s. for cash and £113 for three months, with a dull tendency. Consumptive demand was very small in Europe, but a large quantity of arrival tin was taken out of the English market for shipment to America. In the early part of April sellers were persistent, and in spite of good orders from America values fell away until £113 15s. cash and £111 5s. three months was touched; the downward tendency being assisted by the increase in European stocks of 1,316 tons. Later in the month a good consumptive demand came to the assistance of the market, and prices reached £115 15s. cash and £113 10s. three months. After numerous but small variations in price, final quotations stood at £118 cash and £115 three months. Consumptive demand was good throughout the month both at home and from America. The figures at the opening of May showed a decrease of 3,725 tons in English and Continental stocks. The market opened firm at £118 7s. 6d. cash and £115 for three months, increasing later to £120 10s. for cash and £118 for three months. Eastern sellers were scarce and consumption remaining good, the bulls easily manipulated a rise of £4 per ton for all positions. Toward the end of the month the position became still firmer and the market went up to £130 for cash and £129 5s. for three months. In view of the approach of the Banka sale, however, interested parties endeavored to check the upward rush, and, with an easier feeling apparent in Eastern offers, May ended with prices £129 15s. prompt and £128 10s. for forward. A characteristic of the month was the smallness of the London spot stock, and this gave great assistance to bull operations. The Banka sale realized an average of £129 15s. Consumption was good throughout and tin-plate makers were very busy. Three months tin gained altogether £7 during the month and at one time the backwardation had almost run off. At the beginning of June statistics showed an increase of 2,083 tons in European stocks and prices slowly receded to £127 10s. cash and £124 10s. for three months. A renewal of the American demand strengthened the prices, which jumped to £131 10s. cash with a £4 backwardation on forward. The middle of the month witnessed a keen struggle for

the mastery between bulls and bears, and finally the bears brought three months tin as low as £122 5s. with cash at £127. The loss of the *Asturia* with 750 tons for New York revived prices and the final tone of the market was firm with cash at £129 5s. and three months at £123 and £123 5s. Demand from consumers was sluggish and a good deal of speculative option business was transacted. The East was for the most part a free seller, and a large business was done, but toward the close of the month the tone in this quarter became firmer. The first portion of July was chiefly marked by a great scarcity of warrants for immediate delivery. European stocks decreased 475 tons and business started at £130 10s. for cash. Transactions in three months were very restricted. London spot stock was tightly held, and some buyers had to pay fancy prices in order to cover their obligations. In one case as much as £140 was paid for a parcel of cash tin. Heavy bear selling of forward tin increased the backwardation on three months; at one time this stood as wide as £20 to £25. With large arrivals of metal, prices of cash rapidly fell, and finally closed at £116 for cash and £112 for three months. Consumption on the whole was not very good, most users buying from hand to mouth. Welsh tin-plate makers were very busy owing to the strike in America and bought fair quantities. The Banka sale at the end of the month realized an average of £118 5s. The statistics published at the commencement of August showed an increase of 2,300 tons in the total visible supply and of 3,000 tons in European stocks. The market started firm at £121 7s. 6d. for cash and £117 5s. for three months, but values gradually declined to £116 cash and £113 three months. Extensive realizations forced prices still further down; at one time cash was quoted at £114 and three months at £110 7s. 6d. In the latter part of the month cash tin became scarce and £116 10s. was touched. As the month drew to a close the market was very firm at £118 cash and £115 for three months. A large quantity of tin was shipped to America and there was a good demand from tin-plate makers both there and in this country. The first of September figures were favorable, the decrease for the month being 1,768 tons in European stocks, and the market opened strong at £118 7s. 6d., and £115 three months; later prices steadily receded until £113 15s. for cash and £110 15s. for three months was quoted. Some speculative purchases revived the market slightly, but with the East selling freely and bad reports from America prices slowly sank. The decline was also assisted by the collapse in the copper market. The last week in the month witnessed a general steadying up of prices, and the final quotations were £113 5s. to £113 10s. for cash and £111 10s. for three months. The European demand was fairly good, but there was a serious shrinkage in American consumption of tin for tin-plates due to the steel strike. An increase of 1,005 tons in the stocks at the commencement of October caused somewhat heavy selling and values fell to £109 5s. cash with a backwardation of £2 on three months. Later purchases of cash continued until £115 10s. was paid, but as soon as buying orders ceased prices collapsed, and £112 cash was touched, while forward tin remained unchanged. The latter portion of the month was dull and prices finally closed with cash at £114 to £114 10s. and three months £106 to £107. Demand from home consumers was quiet, but during the first portion of the month America made extensive purchases, the tin-plate works being very busy owing to the ter-

mination of the steel strike. There was no Banka sale during October and the beginning of November figures showed a decrease in European stocks of 1,035 tons. The opening was dull with cash tin fluctuating between £114 and £115, and a backwardation for forward of £5 to £6. Values slowly weakened to £111 10s. cash, with three months at £106 15s. The strong reports from America due to the scarcity of spot tin there strengthened the market and £114 5s. was paid for near dates. In the last week of the month prices were further assisted by bulls calling in cash tin and £118 cash was touched. Realizations, however, quickly followed and the final tone was dull with cash at £113 and three months at £105. The American market throughout the month was considerably above the English level, and at one time prices for immediate delivery touched £156. December commenced with an increase in the visible supply of 2,250 tons, excluding America, and this fact, coupled with the weakness in copper, caused a dull tone throughout the month. On December 20, when it was announced that a large bull operator had suspended payment, there was a rush to sell by people who had to deliver metal to him at higher prices, which caused a very quick break in prices, so that £98 was touched for cash, £97 10s. being accepted for three months. When the most urgent selling had spent itself there was a quick recovery to £101 for cash and £100 for three months. Notwithstanding the continual fall in prices the demand for tin-plates remained good, and the prevailing weakness seems to have arisen more from the growing idea of increased production than of a falling off in consumption. The closing quotations are given as £105 7s. 6d. to £105 10s. for spot, and £104 to £104 2s. 6d. for three months.

TUNGSTEN.

THE production of tungsten ore in the United States during 1901 amounted to 179 short tons of concentrated ore, valued at $27,720 (which was derived from 1,221 short tons of crude ore), as compared with 220 tons of concentrated ore in 1900. The tenor of tungstic acid in the ore ranged from 60 to 70%, and the value of the high quality ore ranged from $102 to $333 per ton, averaging $154·86. During 1901 there were produced in the United States 76,000 lb. of tungsten metal, 13,000 lb. of ferrotungsten and 3,000 lb. tungstic acid and sodium tungstate amounted collectively to 92,000 lb., as compared with the reported production of 172,000 lb. of tungsten and tungsten salts during 1900. The price of tungsten metal varied from 58c. to 64c. per lb. and ferrotungsten from 27c. to 31c. The price of tungsten ore of from 45 to 55% WO_3 is about $2 per unit, while ores of from 65 to 75% WO_3 content command from $2·50 to $3 per unit if free from sulphur and phosphorus. The bulk of the output during 1901 was derived from Colorado, although small quantities were produced from the mines near Lead City, So. Dak., and Long Hill, Conn.; 2,918 tons of crude ore were recorded as having been mined in 1901. Until recently the sources of supply of tungsten ores for the United States were England, Austria-Hungary, Saxony, Germany, and Australia. The growing domestic demand for tungsten to be used in the manufacture of self-hardening tungsten steels has encouraged the exploration for tungsten minerals and the development of the many reported deposits may lead to the replacement of the imported ferrotungsten alloys by those produced from domestic ores. This is particularly pertinent as tungsten minerals in some localities occur with gold and silver ores and the metal may be produced from them to commercial advantage.

The chief use of tungsten is in the use of self-hardening tungsten steel, the metal being used either as ferrotungsten or as the powdered metal. Recently it has been added with very satisfactory results to a copper-aluminum alloy in order to impart greater strength and toughness. It is claimed that the self-hardening property of steel, ordinarily obtained by the addition of tungsten to chrome-steel, may also be obtained by the addition of molybdenum, and in the latter case but one-half the quantity, as compared with tungsten, is needed to produce the same effect. The alloy known as tungsten-ferro-chrome was imported into the United States during 1901 to the value of $9,839, Germany supplying the bulk of the import.

Calcium tungstate is used in the Roentgen ray apparatus on account of its fluorescence. Sodium tungstate is used to fasten the color of certain cotton goods and to render textile fabrics noninflammable. It has also been used to color glass and to some extent in the manufacture of stained paper.

Arizona.—Tungsten ores occur in considerable quantity in the Arivaca district, Pima County, and near Benson, in the Dragoon Mountains, Cochise County. A tungsten ore deposit has been developed 60 miles south of Hackberry, Mohave County, where a seam of wolframite from 2 in. to 6 in. wide occurs in a vein of quartz which varies from 1 ft. to 3 ft. in width. Several tons of ore averaging about 70% tungstic acid were mined but not shipped.

Colorado.—Wolframite and huebnerite ores occur in quantity in Boulder, San Juan, Gilpin, Ouray, and Lake counties. During 1901, however, Boulder County was practically the only producer, the output aggregating 65 tons, averaging 60% tungstic acid and valued at $8,775. The average price received per unit was $2·25, which is equivalent to $135 per ton. San Juan County contributed a small quantity of concentrated ore. The Great Western Exploration & Reduction Co., of Boulder, has been recently organized to mine tungsten ores and to manufacture ferrotungsten. It proposes to concentrate the ores from 20 to 1 and 3 to 1, which will yield concentrates of from 60 to 68% tungstic acid.

Connecticut.—The American Tungsten Milling & Mining Co. has done a small amount of development work at Long Hill, Fairfield County. According to Prof. William Hobbs the scheelite and wolframite occur more abundantly at the lower contact of the intruded beds of crystalline limestone in the diorite and hornblende gneiss of the locality. The mill tests show the proportion of scheelite in the vein to approximate 5%.

Nevada.—Over 1,000 tons of huebnerite ore have been mined at the deposits in the foothills near the base of Wheeler Peak, 12 miles south of Osceola, White Pine County. The formation for several thousand feet up the mountain side is of granite overlain by Cambrian quartzite. There are five prominent veins in the granite which have been traced to the contact with the quartzite but none occurs in the latter. The huebernite vein in the tunnel dips 65° N.W. and is from 18 to 36 in. wide. The ore occurs in crystals up to 3 in. in size in white quartz, although much of the mineral is in fine grains and in irregular bodies. In one locality scheelite also occurs in the ore. Small quantities only of pyrite and fluorite occur as associated minerals. Practically all of the ore shipped has been hand sorted and cobbed or concentrated to an average of 68% WO_3. Hand concentrated samples have averaged as high as 67·5% WO_3.

Oregon.—The scheelite deposits in the Virtue district, near Baker City, Baker County, are reported to carry considerable free gold. The vein material at the water level consists almost entirely of scheelite.

Washington.—The wolframite deposits in Steven County have been exploited to the extent of running in a 50-ft. tunnel upon the vein which is reported to be 4 ft. in width, dipping at about 75°. The wolframite crystals occur disseminated in quartz and specimens were obtained up to 1 lb. in weight. Gold and silver

are associated with the wolframite, but in too small quantities to warrant the working of the property for them alone.

Other States.—Tungsten ore deposits occur also in Oregon, Idaho, Montana, New Mexico, South Dakota and North Carolina. A few tons only for experimental purposes have been produced from these sources during 1901.

Australia.—The production of tungsten ore in Queensland during 1900 amounted to 192 metric tons, valued at £6,605. South Australia contributed 9 tons and Tasmania 18 tons to the total output. A reported discovery of a scheelite deposit in New Zealand was made early in 1902. The lode is stated to be 4 ft. wide and to average 25% scheelite together with 0·65 oz. gold per ton. It is claimed that the ore can be economically concentrated to from 70 to 75% mineral which contains about 80% $CaWO_4$. Scheelite is mined to some extent at Macrae's, Island of Otago, which is the only locality in the colony supplying a merchantable product.

Chile.—During 1900 there were exported from Antofagasta 125 long tons of wolframite, valued at £7,153, and 2 tons of metal, valued at £120.

TECHNOLOGY.

Lewis P. Hamilton and Edgar F. Smith[1] have made in an electric furnace a number of alloys of iron and rare metals, including several with chromium content up to 16%. Among these alloys are copper-chromium, copper-aluminum-tungsten, copper-molybdenum, iron-titanium-tungsten, iron-chromium-titanium, iron-columbian-tantalum and iron-columbium-tantalum-titanium.

The subjoined table gives the analyses of some of these alloys:—

Component.	1	2	3	4	5	6	7	8	9	10	11
	%	%	%	%	%	%	%	%	%	%	%
Iron	5·74	.....	.....	2·71	1·35	2·12	82·15	76·41	53·03	15·78	80·03
Copper	66·88	90·98	95·01	78·53	88·18	34·11	.....	.....	.....	.....	.....
Aluminum	.....	.....	.....	.....	.....	24·89	.....	.....	.....	.....	.....
Chromium	.....	.....	.....	.....	3·22	.....		16·29	40·37	.....	.....
Columbium	}	.....	2·01	.....	.....	.....	.....	.....	}	59·76	10·15
Tantalum	}	.....		.....	.....	.....	.....	.....	}	18·77	2·91
Titanium	.....	3·12	.....	.....	.....	.....	7·28	2·47	2·65	.....	3·18
Tungsten	23·03	.....	.....	.....	.....	32·67	1·66	.....	.....	0·63	.....
Molybdenum	.....	.....	.....	8·58	.....	.....	.....	.....	.....	.....	.....
Silicon	.....	3·51	.....	.....	.....	.....	.....	2·39	.....	.....	2·14
Carbon	.....	2·08	.....	2·42	2·38	.....	2·30	3·14	4·33	.....	1·99
Gangue	5·04	.....	2·57	8·02	4·13	6·56	6·63	.....	.....	5·12	.....
Specific gravity	7·98	7·616	8·38	7·934	8·314	.....	6·707	6·464	.....	.....	.....

[1] *The Journal of the American Chemical Society*, March, 1901, p. 151.

ZINC AND CADMIUM.

THE production of zinc or spelter in the United States during 1901 was the largest annual output yet recorded, and amounted to 140,822 short tons, as compared with 123,231 short tons in 1900 and 129,675 short tons in 1899. The production by districts is shown in the subjoined table.

PRODUCTION OF ZINC IN THE UNITED STATES.

States.	1896.	1897.	1898.	1899.	1900.	1901.
Illinois and Indiana	31,656	38,680	46,693	49,290	37,558	44,896
Kansas	36,566	33,395	38,548	55,872	57,276	74,270
Missouri		18,412	21,063	15,710	20,138	13,063
South and East	9,415	9,900	7,805	8,803	8,259	8,603
Total tons of 2,000 lb.	77,637	100,387	114,104	129,675	123,231	140,822
Total tons of 2,240 lb.	69,319	89,623	101,879	115,781	110,028	132,578
Total metric tons	70,432	91,071	103,514	117,644	111,794	127,751

The large increase in the production of zinc was due to the removal of the smelting plants to the Iola district in Kansas, where the cost of production is considerably less owing to the use of natural gas as a fuel. The output of zinc in Kansas during 1901 was 74,270 short tons, as compared with 57,276 short tons in 1900. A large quantity of zinkiferous lead ores from Colorado was smelted during the year and the zinc content regained. Formerly these low-grade zinkiferous ores were rejected as waste material. The output of the Illinois-Indiana district showed an increase over the preceding year in spite of the removal of a number of the smelting plants to Kansas. The production from this district in 1901 amounted to 44,896 short tons, as compared with 37,558 short tons in 1900. The combined output of the sole producer in the East, the New Jersey Zinc Co., and the chief producer of the South, the Bertha Mineral Co., was 8,603 short tons, as compared with 8,259 short tons in 1900. The ore supply for these works was derived from the mines in New Jersey and in southwestern Virginia. The Joplin district furnished ores for a large part of the Western smelters, although during the past year zinkiferous tailings and zinc ore have been treated in a few of the smelters in Illinois and a considerable quantity was shipped to Europe via Galveston and New Orleans, chiefly to the Vieille Montagne works.

Details of the progress in mining and metallurgy are given by Walter R. Ingalls later in this section under the title "Progress in the Metallurgy of Zinc in the United States during 1901."

Zinc Oxide.—The production of zinc white in the United States during 1901 was 46,500 short tons, valued at $3,720,000, as against 48,840 short tons, valued at $3,677,810 in 1900. The greater part of this output was made by the New Jersey Zinc Co., operating at Jersey City and Newark, N. J., Bethlehem and Palmerton, Pa., and Mineral Point, Wis. Page & Kraus, at St. Louis, produces annually about 450 short tons, and the United States Smelting Co., formerly the American Zinc & Lead Co., of Cañon City, Colo., manufactures a pigment called "zinc-lead," which is a mixture of oxidized compounds of zinc and lead. The production of this special pigment during 1901 was 2,500 short tons, valued at $150,000. The Renfrew Zinc Co. put its new plant at West Plains, Mo., in operation in December, 1901, and the Ozark Zinc Oxide Co. is completing a new works at Joplin, Mo. The estimated annual capacity of each plant is 20,000 tons of zinc oxide. The G. & G. Zinc Oxide Co., which was formed at West Plains, Mo., in 1900, reported no production during 1901.

PRODUCTION OF ZINC OXIDE IN THE UNITED STATES.

Year.	Quantity.		Value.		Year.	Quantity.		Value.	
	Short Tons.	Metric Tons.	Totals.	Per Short Tons.		Short Tons.	Metric Tons.	Totals.	Per Short Ton.
1897.....	26,362	23,925	$1,686,020	$64·20	1900.....	47,151	42,775	$3,772,080	$80·00
1898.....	32,747	29,708	2,226,796	68·00	1901.....	46,500	42,266	3,720,000	80·00
1899.....	39,663	35,982	3,331,692	84·00					

EXPORTS OF ZINC AND ZINC OXIDE FROM THE UNITED STATES. (IN POUNDS.)

Year.	Sheets, Blocks, Pigs, and Old.		Manufactures.	Total Value.	Oxide.	
					Dry.	In Oil.
1897.....	2,557,341	$95,883	$19,431	$115,314	5,564,753	502,357
1898.....	2,742,357	109,634	13,448	123,072	3,342,335	27,050
1899.....	2,985,463	151,956	14,800	166,756	3,012,709	41,699
1900.....	2,013,196	97,762	36,836	134,598	2,618,808	38,706
1901.....	775,881	30,920	42,643	73,563	3,199,778	128,198

EXPORTS OF ZINC AND ZINC OXIDE FROM THE UNITED STATES. (IN POUNDS.)

Year.	Ore and Oxide.		Plates, Sheets, Pigs, and Bars.		Manufactures.	Total Value.
1897.....	*a* 22,220,907	$315,490	28,490,662	$1,356,538	$71,021	$1,743,049
1898.....	*b* 31,413,859	552,064	20,998,413	1,033,959	138,165	1,724,188
1899.....	*c* 67,126,506	1,092,542	13,509,316	742,521	143,232	1,978,295
1900.....	*d* 95,514,893	1,630,043	44,820,577	2,217,963	99,288	3,947,024
1901.....	*e* 88,312,000	1,560,943	6,780,221	288,906	82,046	1,538,636

(*a*) Includes zinc oxide, 3,718,507 lb. ($104,140). (*b*) Zinc oxide, 7,849,059 lb. ($252,194). (*c*) Zinc oxide, 10,685,220 lb. ($366,598). (*d*) Zinc oxide, 11,391,693 lb. ($496,380). (*e*) Zinc oxide, 9,122,283 lb. ($393,259.)

The use of zinc chloride for preserving railroad ties continues to be increased and it is estimated that the nine concerns engaged in this industry during 1901 consume 3,000 short tons annually.

The American Smelting & Refining Co., formerly producers of zinc sulphate as a by-product in smelting lead ores, reports no production during 1901. The Grasselli Chemical Co. is stated to have produced 5,000 lb. of zinc sulphate daily

during 1901. The manufacture of lithophone, which is a pigment consisting essentially of a mixture of barytes with zinc oxide and zinc sulphate, is being carried on to a considerable extent in the United States, chiefly by the New Jersey Zinc Co. and the Grasselli Chemical Co., the latter concern reporting a capacity of output of 10,000 lb. daily. The greater part of the output is consumed in the manufacture of glue and special paints.

Colorado.—According to the Hon. Harry A. Lee, Commissioner of Mines for Colorado, the production of zinc from the ores of that State during 1901 amounted to 13,427 short tons, of which Lake County furnished 11,583 short tons and Mineral County 1,044 short tons. These figures are based on the metallic zinc content of the ores produced. About 70% of the output was exported and 30% treated by domestic smelters, including ore used for the manufacture of zinc-lead pigment at Cañon City, Colo., and possibly some shipped to Mineral Point, Wis., for the manufacture of zinc white. In 1901 the Leadville mills produced 23,261 tons of concentrates averaging 45% Zn, 6% Pb, and 10% Fe. Besides the Leadville product there were also shipments of zinc ore from Silver Plume, Montezuma, Creede and other mining districts. Kansas smelters have received ore from Creede which has assayed as high as 59% Zn, 3·75 to 5% Pb, and about 2% Fe. The high iron content of the blende is due to the iron chemically combined which cannot be removed by any method of mechanical concentration.

The immense deposits of mixed lead and zinc sulphides at Leadville and Kokomo promise to become an important factor in the zinc industry in the near future. The ore is a silver-bearing mixture of galena, pyrite and blende, with very little gangue. As early as 1886 it was milled for its lead content and accompanying silver, the blende being accumulated in tailings heaps. Recently by the application of improved milling methods a closer separation has been obtained and a large quantity of this class of ore has been treated at Leadville, yielding a galena-pyrite concentrate and a ferruginous blende, the latter having a large sale chiefly to European zinc smelters, although a small quantity has been treated at the Kansas smelters. The freight from Leadville via Galveston to Swansea or Antwerp during 1901 was about $9·50 per short ton, and while the miners receive $5 to $7 per ton it is purely a by-product, and the value of the remainder of the ore is increased by its removal. The Colorado Zinc Ore Co. and the New Jersey Zinc Co. are erecting magnetic separating plants at Denver and Cañon City, respectively, to produce ore containing about the same percentage of iron as that which the present concentrating mills are furnishing, but several units higher in zinc and lower in lead. These ores have been smelted direct in Sadtler retorts by the Midland Smelting Co., at Bruce, Kan. The American Smelting & Refining Co. is erecting a zinc smelting plant at Pueblo which will afford a local market for the blende concentrates of Leadville, Kokomo, Montezuma, Creede and other mining districts in the State. The United States Smelting Co. was organized during the year to take over the holdings of the American Zinc-Lead Co., formerly operating the Cañon City plant, which smelts chiefly low-grade zinkiferous lead ores, largely from Utah and Leadville.

The product is copper matte, containing the precious metals, which is shipped or refined. The by-product consists of zinc-lead pigment used largely in the manufacture of paints. The United States Zinc Co., capitalized at $2,000,000, was organized to build a large zinc plant near Pueblo, to handle Leadville zinkiferous ores chiefly from the A. Y. & Minnie mine.

Iowa.—(By S. W. Beyer.)—The production of zinc in the Dubuque region has been reduced to inconsiderable proportions, a condition brought about largely by the sharp decline in the price of zinc, and to a less extent through the exhaustion of the ore bodies in sight. The weak demand and low price have held out no inducements toward the active prospecting and development of new properties as in the years 1898 and 1899. Ore was sold during 1901 at a price which would not cover the cost of production, let alone yielding a reasonable return to the operator. The entire output for the Iowa field scarcely reached 350 tons, principally carbonate, "dry bone," and sold at an average of $7·70 per ton. The most select stock sold for $12 per ton, yielding fair returns to the labor and capital employed, while certain low-grade ores were disposed of at $5 per ton, entailing a considerable loss to those concerned. Almost the entire output was shipped to Mineral Point, Wis. La Salle, Ill., may be considered as a competing market, but rarely affords active competition. The two largest companies remained practically closed or were only worked in a desultory way on account of legal complications. The Alpine Zinc Co. has abandoned the old workings, at least temporarily, on account of water, but has sunk a new shaft on the same vein several hundred yards to the westward, which promises well. A good body of high-grade ore is in sight and will be marketed as soon as the price warrants. The zinc industry in the Dubuque region gives little promise for the future unless prices strengthen materially. The plant of the Dubuque Ore Concentrating Co. was idle during the year because of the intermittent and insufficient supply of crude ore and the general decadence of the industry.

New Jersey.—(Through the courtesy of Mr. A. Heckscher.)—In 1901 the mining operations of The New Jersey Zinc Co. have practically been confined to the Mine Hill deposit, near Franklin Furnace. At the southerly end stripping has been actively followed up and some 45,000 tons of limestone sold and shipped. That portion of the deposit between its southerly termination and the large dike, distant 700 ft. to the north, will probably be stripped and laid bare entirely during 1902. It will then remain to be determined whether stripping shall be carried farther to the north and to what extent. A very large body of ore will be laid completely open and ready for quarrying by the work now in hand. Operations at Mill No. 1 have now ceased and they may not be resumed for some time. It has been found that Mill No. 2 is much in excess of its former rated capacity of 1,000 tons in 24 hours, and it can crush, size and prepare for market readily 70 tons of ore per hour, or over 1,600 tons in 24 hours, which was assumed to be the maximum capacity. Some of the machinery better adapted for fine crushing has been installed and other minor changes ordered. The new mill operates very economically. The over-all cost, disposing of about 700 tons of ore in 10 hours in the most favorable month of the year, has been only 38c. per ton. When it is borne in mind that the ore must be crushed, dried, sized,

cooled, fed to the Wetherill separating machines, and every grain of ore that responds magnetically must be lifted bodily from the conveying belt and carried out of the magnetic field, also that the tails must be jigged to remove the limestone from the willemite, the tails carried away and stored, the willemite again dried and all of the several products assembled in separate bins and shipped, it will be seen that only large capacity, not overstrained, and large output can admit of such low cost. It is believed that 40c. per ton, including repairs and renewals, should cover all costs of crushing, separating and shipping.

The Sterling Hill deposit has not been worked during 1901. The limits of the Franklin deposit are gradually being defined to the north, and this great lense of ore appears to close some 1,200 ft. underground somewhat in the shape of a submerged hammock. It is quite possible, however, that the ore will carry farther to the north than is now indicated by development work.

During the year several outside organizations have continued the active exploration of the belt of white limestone with diamond drills, both between Mine Hill and Sterling Hill and to the north of the larger deposit. Nothing appears to have been found excepting that at one or two points the diamond drill has pierced the magnetic vein which as a rule underlies the Franklinite deposits, but which also is much more persistent than the latter. When these drill records are published they will afford valuable information and will save the necessity of repeating work which is time-consuming and costly.

The output of raw ore from the mine has been as follows: To Mill No. 1, 65,480 long tons; to Mill No. 2, 123,994 long tons. The shipments have been from Mill No. 1, concentrates, 60,319 long tons; from Mill No. 2, crushed ore, not concentrated, 2,621 long tons, and concentrates, 108,016 long tons.

The new mill is operating admirably, and has more than fulfilled expectations. A separate paper by Mr. Stone, furnishing detailed information concerning the central manufacturing plant of the New Jersey Zinc Co., at Palmerton will be found elsewhere in this section.

There were 26,131 long tons of zinc ore, valued at $657,140, exported from New Jersey during 1901, mainly via New York.

Kentucky.—For the six months ending December 30, 1901, the Kentucky Fluorspar Co., at Marion, Crittenden Co., shipped 1,136 short tons of zinc carbonate ore, valued at $13·60 per ton f. o. b. Marion, to Mineral Point, Wis. No zinc blende has been marketed as yet. This is the first recorded shipment of zinc ore from Kentucky for commercial purposes.

Missouri and Kansas.—The production of zinc in Kansas and Missouri during 1901 showed a marked advance over that of the preceding year, the outputs being 87,353 and 77,414 short tons, respectively. The increase was due entirely to the output of Kansas, which was 74,270 short tons in 1901, as compared with 57,276 short tons in 1900, Missouri showing a decrease from 20,138 short tons in 1900 to 13,083 short tons in 1901. There has been no radical change in mining during the year, and a few new discoveries of ore were made southeast from Joplin toward Granby. The milling tendency is toward the production of the highest grade ore possible, and while the standard grade ore is 60% Zn and but 8% siliceous gangue, certain mills make a product assaying as high as

64·5% Zn. Magnetic concentration has been satisfactorily applied to ore high in pyrites and two new magnetic separators of the Cleveland-Knowles and the Waring types are being exploited with promising results.

At present the deepest deposit being worked in Missouri is 250 ft., while the average is about 100 ft. The record of prospect drilling in Missouri given in the following table is of interest:—

Holes Drilled.	Depth.	Ore Found.	Holes Drilled.	Depth.	Ore Found.	Holes Drilled.	Depth.	Ore Found.	Holes Drilled.	Depth.	Ore Found.
	Ft.	%		Ft.	%		Ft.	%		Ft.	%
500	50	3	100	300	None.	8	700	None.	2	1,100	50
450	100	8	25	400	None.	7	800	None.	2	1,200	None.
400	150	25	12	500	75	6	900	50	2	1,400	None.
125	250	34	8	600	50	6	1,000	None.	1	2,005	None.

THE PRODUCTION OF ZINC AND LEAD ORE IN THE JOPLIN-GALENA DISTRICT, 1894 TO 1901 (INCLUSIVE).

Years.	Zinc Ore.	Lead Ore.	Total Value of Both Ores.	Year.	Zinc Ore.	Lead Ore.	Total Value of Both Ores.
	Short Tons.	Short Tons.			Short Tons.	Short Tons.	
1894.....	147,310	33,190	$3,535,736	1898..... ...	234,455	26,687	$7,119,867
1895.....	144,487	31,294	3,775,289	1899.....	255,088	23,888	10,715,307
1896.....	155,333	27,731	3,857,355	1900.....	244,629	29,176	7,986,622
1897.....	177,976	30,105	4,736,302	1901.....	256,220	34,238	7,989,230

AVERAGE BASE PRICES OF ZINC AND LEAD ORES IN THE JOPLIN DISTRICT.

Month.	1900.		1901.		Month.	1900.		1901.	
	Zinc, per Short Ton	Lead per 1,000 Pounds.	Zinc, per Short Ton	Lead, per 1,000 Pounds.		Zinc, per Short Ton	Lead, per 1,000 Pounds.	Zinc, per Short Ton	Lead, per 1,000 Pounds.
January.....	$30·23	$28·00	$23·73	$22·80	August.....	$25·67	$23·00	$23·88	$22·90
February....	29·36	27·50	23·96	22·50	September..	24·55	23·00	22·82	23·16
March.....	26·45	26·00	23·70	23·10	October.....	24·26	22·71	24·63	23·15
April.....	23·42	26·86	24·58	22·76	November..	24·45	23·80	26·15	23·14
May.....	26·92	24·50	24·38	23·49	December...	25·40	22·19	23·24	22·85
June.....	25·00	21·80	24·22	23·52					
July.....	24·23	21·36	24·36	23·49	Average..	$26·50	$24·16	$24·21	$22·99

The exports of zinc ore from the Joplin district during 1901 amounted to 13,294 long tons, valued at $410,544, all shipped via New Orleans except 291 long tons via Galveston.

The center of the zinc smelting industry in Kansas is the Iola district, comprising Iola, Gas City and La Harpe. Outside of this district the only large smelter is that of the Edgar Zinc Co., at Cherryvale. The old plants at Pittsburg and Weir were idle during the year. A few furnaces have been operated at Girard and the small works at Bruce have smelted Colorado ore direct in Sadtler retorts.

Full details of mining and milling in the Joplin district are given in the separate article by Mr. Frank Nicholson later in this section. An unsuccessful attempt was made toward the close of 1901 to consolidate a number of the more important Western zinc smelting works under the name of the Zinc Smelting Corporation, with a capitalization of $50,000,000.

Virginia.—The Bertha Mineral Co. now operates the only zinc smelting works in the South. The plant consists of 10 large, direct-fired, Welsh-Belgian

furnaces, pottery, kilns, roasters and necessary accessories. At these works the practice is maintained to a high state of efficiency, and while minor improvements have been made from time to time, no radical changes have been made for some years past. In common with Eastern zinc manufacturers, the competition of Western smelters using cheap natural gas fuel has been felt, but the superior purity of the spelter produced from the Southern and Eastern ores, as compared with that made in the West, together with its higher price has offset to some extent the advantage of cheapness of the Western product. There are only three active zinc mines in the South—the property of the Wythe Lead & Zinc Mine Co., at Austinville, Va., the Bertha mines, in Wythe County, Va., both quite well-known properties, and the Clark mine in Pulaski County, Va., an operation of more recent development; all of these mines are tributary to the Bertha Mining Co.

At Austinville, Va., work has been carried on actively during the year 1901, the chief output being zinc ore of the calamine variety, while lead carbonate and limonite iron ore have also been produced. Additional water power is being developed to be utilized for an electric haulage plant; in order to get at rich deposits of calamine it is necessary to strip about 15 acres of ground, carrying a clay over-burden from 50 to 100 ft. thick, and for this very large undertaking the new haulage plant is being added.

At the old Bertha zinc mines, the work of stripping the clay over-burden is being vigorously and constantly carried on. As this clay contains valuable limonite ore it is washed and the product shipped to blast furnaces in Virginia.

At the Clark mine, in Pulaski County, both iron and zinc ores are being produced. The minerals are so intimately mixed that it is necessary to separate them by magnetic treatment.

While the usual amount of activity in prospecting is noted, yet it may be positively stated that no new producing zinc mines have been developed in this part of the South. In the zinc belt near Knoxville, Tenn., there has, perhaps, been unusual activity, yet practically no shipping ore has been discovered in this territory. The ore found is of the disseminated blende character, occurring in magnesian limestone. While these deposits appear to be quite common and to cover a large territory, experience seems to indicate that, owing to their leanness, they cannot be worked profitably.

Wisconsin.—(By S. Weidman.)—The lead and zinc region of Wisconsin, which was described in THE MINERAL INDUSTRY, Vol. IX., comprises an area of about 2,000 square miles, in Iowa, Grant and La Fayette counties, in the southwestern part of the State. The main ore-bearing formation consists of a stratum of magnesian limestone, the Galena limestone, having a thickness of about 250 ft., lying nearly horizontal and forming the surface rock throughout the greater part of the region. The ores are also found to a minor extent in the limestone formation, the Trenton, and other formations of the Lower Silurian occurring at or near the surface. The vertical order of occurrence of the ore in the district is commonly as follows: Above the level of ground water the dominant valuable minerals are galena and smithsonite; with the galena there is some cerussite and less anglesite, and with the smithsonite there is some sphalerite. The smithsonite may locally

occur to a depth of from 15 to 30 ft. below the level of ground water. Below the galena and smithsonite, sphalerite occurs associated with marcasite.

It is the generally accepted theory that the material of these ores was originally widely dispersed through the sedimentary rocks, especially the limestone. By the action of the circulating ground water, ascending and descending through the crevices and openings in the rocks, the disseminated material of the ore was concentrated into ore bodies. The sheets of ore are found largely between the beds, in vertical and in inclined fissures called locally flats, openings and pitches. The ore bodies are usually connected with one another, and are of quite variable dimensions, ranging in thickness from a fraction of an inch to over a foot. Definite figures on the output of lead and zinc ore in Wisconsin for the past year are not available at the present time, but there is a general report of increased activity in mining throughout the year. A survey of the lead and zinc deposits of the State by the Wisconsin Geological and Natural History Survey is in progress at the present time.

At Mineral Point the New Jersey Zinc Co., operating the Grillo-Schroeder process, manufactured sulphuric acid grading from 66°B. to monohydrate and up to 40% of fuming acid. This company has licensed a plant at Repauno, and that of the Dupont Chemical Works, both on the Delaware river; also one in New Mexico, and a large plant on the Pacific coast.

PRODUCTION OF ZINC IN THE WORLD. (IN METRIC TONS.)

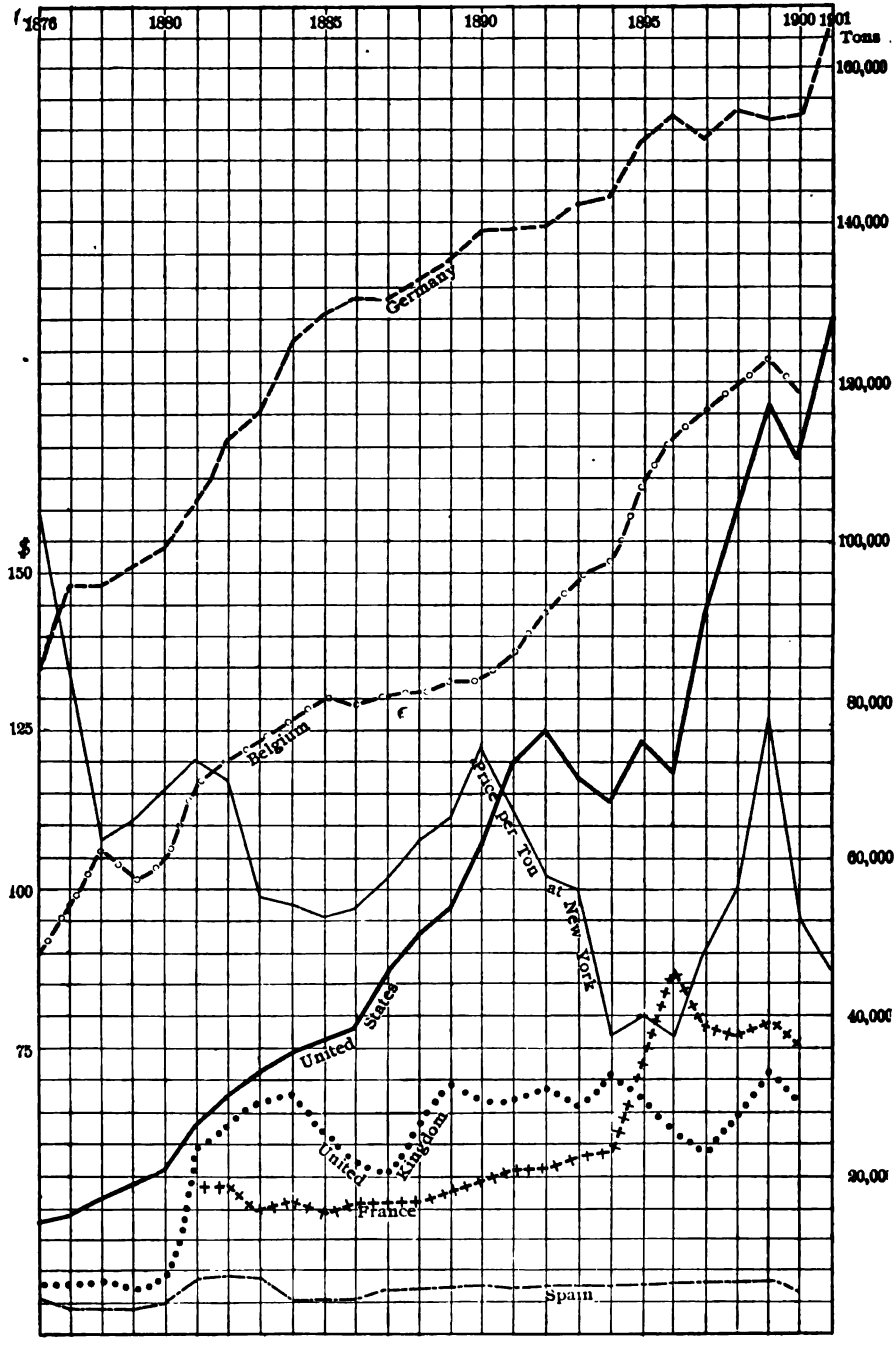
Year.	Austria. (a)	Belgium. (b) (f)	France. (b)	Germany (b) (f)	Italy. (b)	Russia. (b)	Spain. (b)	United Kingdom. (c)		United States. (e)	Totals.
								Native Ores.	Foreign Ores.		
1897	6,286	116,067	88,067	150,739	250	5,868	6,244	7,169	16,648	91,070	488,346
1898	7,302	119,671	87,155	154,867	250	5,664	6,031	7,162	21,225	108,514	462,237
1899	7,192	122,843	89,274	153,155	251	6,331	6,184	8,837	23,385	117,644	485,246
1900	6,742	119,317	86,305	155,799	250	5,967	5,611	30,307		111,794	472,092
1901	6,573	(d)	(d)	166,283	250	(d)	(d)	9,211	(d)	127,751	.....

(a) The statistics for Austria are taken from the official reports of the Mines Department, except for 1900, for which the figure reported by Henry R. Merton & Co. has been used.
(b) Official statistics, except for 1901.
(c) The statistics for the United Kingdom are arrived at by deducting the zinc produced from domestic ores, as reported in the official Blue Books, from the total output of the smelting works as stated in the reports of Messrs. Henry R. Merton & Co.
(d) Statistics not yet available.
(e) Statistics compiled from direct returns by the producers to THE MINERAL INDUSTRY.
(f) According to Henry R. Merton & Co., Belgium, Holland and the Rhine district of Germany in 1901 produced 202,474 metric tons of spelter, against 189,301 metric tons in 1900 and 192,994 in 1899.

PRODUCTION OF ZINC ORE IN EUROPE. (IN METRIC TONS.)

Year.	Algeria.	Austria.	Belgium.	France.	Germany.	Greece. (b)	Italy.	Norway. (a)	Russia.	Spain.	Sweden.	United Kingdom.
1896.....	17,587	26,887	11,630	81,346	729,942	22,700	118,171	450	59,680	64,828	44,041	19,629
1897.....	32,269	27,463	10,954	83,044	663,850	30,906	122,214	908	54,524	73,848	56,636	19,587
1898.....	29,800	27,395	11,475	85,550	641,706	32,045	132,099	320	(d)	99,836	61,627	23,929
1899.....	42,970	37,100	(d)	84,813	664,536	22,907	150,629	379	(d)	119,710	65,159	23,505
1900.....	30,281	38,243	144,033	67,059	699,215	18,751	139,679	(d)	(d)	86,158	.....	25,970

(a) Zinc-lead ore. (b) Including blende and calcined calamine. (d) Statistics not yet published.



THE WORLD'S PRODUCTION OF ZINC

IN METRIC TONS

The Spelter Markets in 1901.

New York.—The market was very steady, being free from the wide fluctuations that have characterized former years. With the exception of a few isolated lots shipped on old contracts, no spelter was exported. The European market was not in a position to take additional quantities from this side without depressing prices still further, for in consequence of the lessened consumption European producers felt compelled to reduce production, in order to guard against a further decline in values. It seemed absolutely necessary for the foreigners to have recourse to such concerted action, in view of the fact that the spelter industry had entered a phase which meant severe losses. The unprecedented advance in the price of coal and the higher rate of wages which were established during the last two years, added heavily to the cost of producing the article, and the result was in most, if not all cases, that producers were doing a losing business. Under these circumstances it was a matter for congratulation that our domestic demand proved fully sufficient to absorb the entire production of the United States. In spite of the steel strike, the galvanizing industry, which forms the principal outlet for the consumption of the metal, was very active with but short interruptions. The sheet zinc business was satisfactory in price as well as volume, and the brass trade consumed considerably more than in any previous year. The many avenues through which spelter enters into use for electrical purposes, such as telegraph and storage batteries, called for larger quantities, as did also the industries in which zinc oxide seeks its outlet. On the other hand, the output of zinc ores continued very large, although several of the companies floated a year or two ago, met with disaster. While some shipments of Joplin ores were made to the other side, mainly with a view to stimulating competition, the capacity of the smelting plants now in operation is more than sufficient to treat the present output. Colorado has supplied a moderately large tonnage of ores and indications are that shipments from that direction will show a large increase during the coming year. January opened rather dull at about 4·125c. New York, consumers pursuing a hand-to-mouth policy, but producers not pressing sales. As the year progressed, the market weakened, in spite of a shut-down of about 60% of the mines and a good consumption; and 3·75c. St. Louis and 3·95c. New York was reached by the middle of February. From this figure there was a slight recovery, only to give way to renewed depression. During April, however, some speculative buying set in and the market displayed considerable activity. Quotations of 3·875c. St. Louis and 4·05c. New York was reached in June. During the summer months, the steel strike prevented any undue upward movement,

AVERAGE MONTHLY PRICES OF SPELTER IN NEW YORK.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.	Cts.
1896	3·91	4·02	4·12	4·13	4·21	4·21	4·32	4·26	4·18	4·17	4·08	3·89	4·12
1897	3·96	4·04	4·25	4·26	4·27	4·77	4·66	4·58	4·67	4·98	5·29	5·10	4·57
1898	5·34	6·28	6·31	6·67	6·88	5·98	5·82	5·65	5·50	5·32	4·64	4·66	5·75
1899	4·65	4·64	4·60	4·71	4·53	4·29	4·28	4·17	4·11	4·15	4·29	4·25	4·39
1900	4·13	4·01	3·91	3·98	4·04	3·99	3·95	3·99	4·08	4·23	4·29	4·31	4·08

and it was not until the middle of September that matters began to improve. A lively demand developed for early shipments and prices advanced to 4·25c. New York in October, and 4·325c. in November. The closing figures at the end of the year were 4·15c. St. Louis and 4·3c. New York, with stocks in first hands comparatively small. Negotiations were undertaken with a view to a consolidation of the principal smelting works, but the plan did not materialize.

London.—January opened with a steady market at £18 17s. 6d. for ordinaries, and £19 for specials. There was a fair amount of buying by consumers, but toward the end of the month the American dealers showed themselves willing to sell at the European parity, and this caused values to recede to £18 5s. for ordinaries. Continental makers also sold freely, thus helping the fall. February again witnessed a further shrinkage, owing to a continuance of Continental offers, but America was somewhat better and offering from that quarter ceased. Values continued to drop throughout the month, until it finally closed at £17 5s. Consumers bought freely throughout, having good orders placed, principally in the galvanizing and kindred trades. March was also to be a month of declining rates, and although consumers were tempted to buy ahead and book good quantities, their purchases were not enough to stem the tide of selling, which set in from Europe, where all makers seemed to be rather heavily stocked. The lowest figure touched this month was £16 for ordinaries, specials being held for about 10s. more. Just at the close of the month there was a rally, chiefly induced by speculative buying and a withdrawal from the market of some of the chief sellers. The close was consequently strong at £16 17s. 6d. ordinaries, and £17 for specials. April commenced with a quiet tone and prices drifted back again to the region of £16. At this time there was a meeting of the principal producers on the Continent to come to some arrangement, whereby they might restrict output and so keep values from declining. This caused a quick reaction from the bottom, and £17 2s. 6d. was paid for ordinaries. This conference was postponed constantly throughout the remainder of the year, but no definite agreement was come to. Continental producers took the opportunity of clearing out good quantities at these figures, which led to a set-back early in May to about £16 18s., only to advance again rapidly to about £18, but a further reduction was apparent toward the end of the month, when the ruling figure was £17 15s. for ordinaries and £18 for specials. Consumers bought freely throughout in the hopes that a speedy arrangement would be arrived at by the producers. Zinc sheets and galvanized iron were in good demand, large orders for the latter article being placed for the South African market. June, until about the middle of the month, was very quiet, but a little buying kept the tone steady at about £17, but toward the end of the month a quick break occurred, owing to heavy pressure of Continental sales, so that when July began the value of ordinaries was no more than £16 10s., specials being held for about 5s. more, and the market was steady throughout the month, prices only fluctuating to the extent of a few shillings, closing figures being practically those last mentioned. August opened with a fair inquiry at about £16 10s., but steady buying caused a revival to about £17, which was about the nearest price when the month ended. September saw values steadily maintained within 5 shillings either way of £17, and although consumers were busy,

there was enough spelter offering from the Continent to keep values from rising much. All the upward movements in October were induced by rumors as to the success of the Producers' Convention, but no confirmation of any agreement was forthcoming. Prices oscillated between £16 18s. 9d. and £17 2s. 6d., and closed about the lowest. November opened with a quiet market and a falling tendency, most producers seeming quite willing to meet the demand at current values. Business was done as low as £16, and as high as £16 17s. 6d., but the end of the month witnessed the lowest figure. December found spelter depressed in sympathy with all other metals, and prices dropped to £16 5s., but rallied toward the middle of the month, on the renewed reports that the European producers had at last come to a definite understanding. The highest point reached was about £17 for ordinaries, specials being held for about 5s. advance, and a good business was done on the advancing market, but when the above figure had been reached there was a tendency to recede, caused, no doubt, to a great extent, by the depression in the other branches of the trade. The year closed with good ordinaries selling at £16 15s., and specials at £17.

Breslau.—The quarterly average prices of spelter during 1901, as reported by the Royal Mining Office at Breslau, were as follows, the quotations being in marks (23·8c.) per 50 kg.

	1895.	1896.	1897.	1898.	1899.	1900.	1901.
First quarter.....	12·50	13·50	16·00	16·50	25·00	20·00	16·00
Second quarter.....	13·00	15·50	15·50	17·50	26·00	20·00	15·50
Third quarter.....	13·50	15·50	15·50	19·00	22·50	18·00	15·00
Fourth quarter.....	13·50	11·00	16·50	22·00	19·50	17·50	15·00
Average.....	13·12	15·12	15·87	18·75	23·25	18·87	15·88

The production of crude zinc was 107,967 tons, valued at 34,636,000 marks; of metallic cadmium, 13 tons. The output of calamine was 219,332 tons, of blende 253,770 tons; while from the furnaces 3,013 tons of zinc sponge (Schwamm) and 3,604 tons of ashes, oxide and waste were recovered. The consumption of coal was 1,160,052 tons.

A Review of Progress in the Metallurgy of Zinc in 1901.

By Walter Renton Ingalls.

The last year was characterized by the introduction of numerous improvements in the metallurgy of zinc, which tend to cheapen the cost of production and render available supplies of ore that have not been capable of profitable exploitation heretofore, without there having been any radical innovation. About the same number of new processes for the treatment of mixed sulphides has been patented as in former years, but in so far as practical results are concerned the satisfactory solution of this problem appears to be as far away as it was at the beginning. Messrs. Ashcroft and Swinburne have been continuing in England their experiments with the Phœnix process of electrolytic smelting, with successful results it is claimed, but so far they have not gone beyond the experimental stage; especial interest is attached to their proposals because of the novelty of their nature. In the meanwhile progress is being made in the distillation of charges high in iron and lead by the ordinary method of zinc smelting, with subsequent recovery

of a portion of the lead and silver values from the residuum, which procedure, aided by the more perfect preliminary preparation of the mineral that can in many cases be effected by means of the Wetherill magnetic separators, constitutes a real advance in the art.

ECONOMIC CONDITIONS.—There was an improtant increase in the production of spelter in the United States; the output of Europe increased also, the production of Upper Silesia having advanced from 102,213 metric tons in 1900 to 107,045 metric tons in 1901, which was an unusually large gain for that district, while the output in Rhenish Prussia, Westphalia, Belgium and Holland jumped from 189,311 metric tons to 202,485. Increasing production in Europe in the face of the generally depressed industrial conditions, especially in Germany, caused the price of spelter to rule low (the average for the year was only £17 0s. 6d. at London) and the cost of coal continuing high, the production of spelter could hardly have been conducted there on a satisfactory basis. In the United States the consumptive demand was sufficiently large to absorb the entire domestic production at a higher scale of prices than prevailed in Europe and there was consequently no exportation of spelter from this country in 1901, save the comparatively small quantity of high-grade Eastern spelter, which is shipped abroad under any circumstances.

Closing of Old Works.—The year 1901 witnessed what is practically the end of the direct-firing coal smelteries of Missouri and Kansas, at least for the present or so long as the natural gas holds out. Several of the old plants which were closed in 1900 were dismantled and others are being permitted to fall gradually to pieces through idleness and decay; there is little likelihood that any of them will be of further use in their present form. The few coal smelteries that were in operation during 1901 comprise the works at Collinsville, Ill. (which were closed in August), the Carondelet works of the Edgar Zinc Co., and the small plants at Bruce and Girard, Kan., and Rich Hill, Mo. It may be remarked incidentally that the works at Girard and the two plants of the Edgar Zinc Co. are controlled by the United States Steel Corporation, which obtains therefrom about 25,000 tons of spelter per annum, or about 50%, more or less, of its own requirement of spelter for galvanizing purposes. The great center of the Western zinc smelting industry is now the Iola district, comprising the environs of the town of Iola, Kan., and the near-by towns of Gas City and La Harpe. Outside of that district the only large smelting plant in Kansas is that of the Edgar Zinc Co., at Cherryvale.

New Plants.—The Lanyon Zinc Co. and George E. Nicholson, both at Iola, and the Edgar Zinc Co., at Cherryvale, added new furnaces to their plants in 1901. A new plant of 1,800 retorts was erected by A. B. Cockerill, at Gas City, near the existing plant of the Prime Western Spelter Co. Another new plant, comprising a sulphuric acid department, was erected by the Standard Acid Co., at Iola, near the Nicholson works. The ore is to be roasted by means of a modification of the Hegeler furnace and the acid department is designed to turn out a product of 60°B. strength. The United States Zinc Co., composed of interests which are important in the American Smelting & Refining Co., made arrangements for the erection of a zinc smelting plant at Pueblo, Colo., which will afford

a local market for the blende concentrate of Leadville, Kokomo, Montezuma, Creede, Rico and elsewhere in Colorado. The Lanyon Zinc Co. and the New Jersey Zinc Co. built rolling mills during the year (at La Harpe, Kan., and Palmerton, Pa., respectively) which will begin operation in 1902. The outcome of the advent of these concerns into the sheet zinc business, wherein the Matthiessen & Hegeler Zinc Co. and the Illinois Zinc Co. have heretofore had an extremely profitable monopoly, is awaited with interest.

The Palmerton Works of the New Jersey Zinc Co.—The new plant of the New Jersey Zinc Co., at Palmerton, Pa., which has been under construction for several years, was described recently by Mr. George C. Stone, the chief engineer of the company.[1] This is not only the most modern, but also is the most comprehensive works for the treatment of zinc ores in the United States. The plans of the company contemplate an ultimate capacity for producing annually 60,000 short tons of zinc oxide, 30,000 short tons of spelter and 72,000 long tons of spiegeleisen. In addition to those departments there is a sheet zinc rolling mill, a catalytic sulphuric acid installation, and a lithophone plan of five tons capacity per day.

The works are situated on the edge of the anthracite coal field, about 9 miles east of Mauch Chunk. The ore, coal, limestone and other supplies are delivered by the Central Railroad of New Jersey to the zinc company, which does its own switching. The cars are passed over an all-steel, 100-ton track scale, or over a turnout which avoids the scale, to a double track trestle, the latter rising at a 2% grade for 1,000 ft. and extending 2,000 ft. further at an elevation of 30 ft. above the ground level. The space under the trestle is occupied by bins, each 20 ft. high and 25 ft. wide, which have chutes, accessible from cross-galleries, for the delivery of coal and ore into wheelbarrows. South of the trestle there is a storage yard, 100×2,000 ft., which will hold 60,000 tons of ore, and a like quantity of coal; this yard is commanded by a Brown traveling bridge, which will take material from the bins to any part of it, and vice-versa.

The zinc oxide plant is located north of the trestle. The furnace house is 50×1,260 ft., and contains 288 furnaces, built back to back in blocks of 12, each block being an independent unit. North of the furnace house are the blower houses, one for every two blocks, each containing two blowers driven by directly connected motors. North of these are the settling towers and exhaust-fan rooms, each of the latter containing eight directly driven fans. Still further north are the bag-rooms, of which there are four. The bag-rooms have an aggregate floor area of nearly 2 acres (87,120 sq. ft.) and contain over 27 miles of bags, which have a total surface of 850,000 sq. ft. The bag-rooms occupy three sides of a rectangle, the packing house filling up the fourth side. The packing house is 62 ft. wide and 143 ft. long, four stories high. The first and fourth floors are for the storage of unpacked oxide. The latter is lifted by an electric elevator to the top of the building, whence it is led through chutes to bolting machines on the third floor and thence to packing machines on the second floor. Bags are sewed and cleaned on the third floor. North of the packing house there is a cooperage building and four storehouses, the latter having an aggregate floor area

[1] *Engineering and Mining Journal*, April 5, 1902.

of 63,000 sq. ft. and capacity for 9,000,000 lb. of oxide. The cooperage building is 82×160 ft., two stories high. The lower floor is used for stock storage and drying rooms; the barrels are made on the upper floor and are conveyed thence over bridges to the packing house. Automatic sprinklers safeguard the building against fire.

The oxide furnace house is built entirely of iron and steel. The working floor is 10 ft. above the ground level, affording room for collecting hoppers for the residuum, which is drawn from them into steel cars and trammed by locomotives to the spiegeleisen department. The fan rooms and blower houses have brick walls and steel, trussed roofs.

East of the oxide department is the power plant, which is centrally located with respect to the entire plant. The boiler house lies just to the north of the trestle, its south side serving as a retaining wall for coal dumped from the trestle. The coal is drawn through openings in the wall and discharged directly in front of the boilers. The boiler house is 56 ft. wide and will be eventually 320 ft. long. It now contains 16 return tubular boilers, each 6 ft. in diameter and 20 ft. long, equipped with Wilkinson automatic stokers and arranged also to be fired with the waste gases of the blast furnaces. The engine house, which is situated north of the boiler house, is 64×270 ft., the main floor being 10 ft. above the ground level. A 40-ton crane traverses the entire building and a standard gauge track runs into it. The walls are of brick; and the roof slate, laid on 3-in. plank carried by steel trusses. There are now installed two Dickson-Corliss horizontal, cross-compound engines, each of 800 H.P., directly connected with a 600-kw. (250 volts) Crocker-Wheeler generator. There is room for another generating set of the same type. Two 150-kw. Crocker-Wheeler generators, directly connected with Payne horizontal, tandem compound engines are in reserve. There is also room for three blowing engines, of which only one has yet been installed; this is a horizontal, cross-compound Southwark-Corliss, with 26-in. and 46-in. steam cylinders, 54-in. air cylinders, and 48-in. stroke.

The spiegeleisen blast furnaces are situated east of the power plant. Room has been provided for four, but only one has yet been built. This is 60 ft. high, with bosh 14 ft. in diameter. A Brown automatic hoist and charging apparatus is used. Upright flue-dust catchers are installed in duplicate. South of the furnace are five 32-pipe Cooper stoves, one of them being held in reserve. Then follows the stock house, containing 18 circular steel tanks, set on concrete walls, for the storage of fuel and limestone, a steel trestle extending over them.

The spelter department is placed to the east of the spiegeleisen furnaces. At present it comprises two large regenerative gas-fired furnaces, which are erected in a brick building, with steel truss roof, 66×240 ft. The working floor is 14 ft. above the ground level, this arrangement conforming to the latest tendency in such installations. North of the furnace house are 11 Taylor gas producers, in a steel building 43×91 ft., and a boiler house, 54×60 ft., containing two 250-H.P. Babcock & Wilcox boilers for blowing the producers and heating the retort drying rooms. There are also annealing furnaces, clay sheds and a pottery, the last being provided with hydraulic presses. South of the spelter plant are the sulphuric acid and lithophone departments.

The works are equipped with an elaborate system of tramways, water supply and electric lighting; and also with a very complete installation of construction and repair shops.

The Census Report.—Bulletin No. 124 of the Twelfth Census, entitled "Lead, Copper and Zinc Smelting and Refining," has recently been issued. The statistics collected for it cover the calendar year 1899; unfortunately the conditions of that year in so far as the zinc smelting industry is concerned were peculiar and abnormal, which fact must be borne in mind in considering its statistics. The latter are reported by States and include the returns of smelters who produce zinc white, sheet zinc and sulphuric acid besides spelter, wherefore a purely technical analysis of the data is limited to results of comparatively little value. The statistics as reported by the Census, with the interpolation of some averages, are summarized in the following table:—

	United States.	Illinois.	Indiana.	Kansas.	Missouri.	Pennsylvania.	Other States. *a*
Number of Works.	31	5	3	11	5	3	4
Capital invested (*b*):							
Land	2,243,876	188,100	7,250	1,684,026	25,500	59,000	280,000
Buildings	5,470,590	637,434	108,454	2,206,702	288,000	1,150,000	1,080,000
Machinery, tools and implements	1,935,754	1,095,041	21,690	405,464	77,300	190,000	146,259
Cash and sundries	4,491,590	1,315,744	7,441	922,337	413,229	472,626	1,360,213
Total	14,141,810	3,186,319	144,835	5,218,529	804,029	1,871,626	2,916,472
Tons of ore smelted	468,609	92,400	10,359	131,407	42,584	45,627	141,232
Tons of dross smelted	12,578	2,427	.....	.....	.....	9,569	582
Tons of spelter produced	131,546	46,759	4,359	54,516	18,107	4,781	4,024
Tons of sheet zinc produced	17,723	17,723	.....	.....	.....	.....	.....
Tons of sulphuric acid produced	58,828	58,828	.....	.....	.....	.....	.....
Tons of acid phosphate produced	7,512	7,512	.....	.....	.....	.....	.....
Tons of zinc oxide produced	37,557	.....	.....	.....	.....	9,644	27,913
Average value of spelter per ton (*c*)	$108·49	$103·59	$103·24	$106·21	$111·10	$188·17	$133·09
Average value of sheet zinc per ton (*c*)	140·80	140·80	.....	.....	.....	.....	.....
Average value of sulphuric acid (*c*)	7·22	7·22	.....	.....	.....	.....	.....
Average value of zinc oxide per ton (*c*)	72·39	.....	.....	.....	.....	80·84	69·46
Number of men employed (*d*):							
Maximum	5,944	1,641	190	1,958	537	751	867
Minimum	4,473	1,476	140	1,186	433	593	645
Average	4,869	1,551	119	1,487	500	448	764
Total horse power of engines	12,546	3,294	280	2,330	675	3,921	2,096
Cost of production:							
Ore (*e*)	$10,995,846	$3,669,953	$326,191	$4,317,628	$1,503,670	$362,792	$915,112
Dross (*e*)	644,645	124,340	.....	.....	.....	506,242	14,063
Fuel	751,839	261,661	8,058	129,173	93,534	60,591	199,822
Rent of power and heat	75,000	.....	.....	75,000	.....	.....	.....
Mill supplies	83,845	24,977	1,145	10,452	2,412	14,962	29,897
Other material	436,378	205,538	6,836	41,103	33,871	45,605	103,425
Freight	298,505	130,346	44,669	105,590	17,900	.....	.....
Labor	2,355,921	758,912	58,188	705,808	268,196	174,510	390,362
Salaries	440,200	229,022	7,650	60,800	36,880	13,669	99,179
Other general expense (*f*)	399,472	109,407	5,588	81,169	36,908	4,869	161,536

(*a* Includes two works in New Jersey and one each in Virginia and Wisconsin. (*b*) Includes the value of land, buildings, machinery, tools and implements and the live capital utilized, but does not include the capital stock of any corporations reporting. (*c*) Values at the works where produced. (*d*) Includes women and boys, of whom the number is insignificant; does not include proprietors, managers, superintendents, clerks and salesmen. (*e*) Cost delivered at the works. (*f*) Does not include selling expense, interest on capital or amortization of plant.

The above works produced only spelter, no by-products being recovered. Under the caption of fuel, the coal and coke used for reduction material is doubtless included, although not so stated in the report. It is not stated what value, if any, is put on the natural gas consumed.

The production of the works of Indiana, Kansas and Missouri and the labor and fuel cost per ton of spelter, segregated according to the fuel used, is given in the table on the following page.

Natural Gas.				Coal.			
	Spelter. Short Tons.	Wages per Ton.	Fuel per Ton.		Spelter. Short Tons.	Wages per Ton.	Fuel per Ton.
Kansas.....	40,125	$12·03	$1·38	Kansas and Southwestern Missouri.	24,219	$15·53	$4·19
Indiana.....	4,359	13·34	2·99	St. Louis district....	14,151	14·06	5·68

Referring to the first table, it is to be remarked that the great difference in the values of the spelter produced in the East and the West, *i.e.*, 6·65@6·90c. vs. 5·10@5·55c. per lb., is due partly to the superior quality of the former metal. Also it is to be borne in mind that there were wide fluctuations in price in 1899 and the period of the year at which the product was sold would make a great difference. In the latter half of the year most of the Western smelters were operating at a greatly reduced rate and some closed their works entirely.

BLENDE ROASTING.—In the blende roasting practice in the West conditions remain the same as heretofore, some of the works employing long mechanically-raked furnaces and some of them continuing to use hand-raked shelf burners. The new works of the Standard Acid Co. has a modification of the Hegeler furnace, which is adapted to utilization of the sulphurous gas for acid manufacture; the new plant of A. B. Cockerill has hand-raked shelf burners. The cost of roasting with the aid of natural gas in the Iola district, both with hand-raked and mechanically-raked furnaces, is phenomenally low; in the former, the work is done by contract at 5c. per 100 lb. of roasted product, or $1 per ton, at which rate the men earn $2@$2·20 per day, according to the season of the year. (In the cool weather the men roast more ore than in the extremely hot weather of the Kansas summer.) A cost of $1 per ton of roasted ore corresponds to approximately 85c. per ton of raw ore, dry basis.

Numerous new mechanical roasting furnaces were patented in 1901, none of them being designed especially for blende roasting, however, with the exception of that which was invented by Mr. Joseph P. Cappeau, general manager of the Lanyon Zinc Co. and was put in practical use at one of the Iola works of that company. This furnace is more or less a modification of the Ropp furnace; the space under the hearth is entirely clear, however. The patent specifications claim: "A roasting furnace comprising a hearth supported on standards to permit free circulation of air beneath the floor of said hearth, an opening in said floor for permitting the passage of air into the hearth, and adjustable means for controlling the passage of air through said opening."[2] The new Spirek furnace, which was designed originally for the reduction of quicksilver ore, has been adapted to blende roasting, and an installation for that purpose has been made in Italy, as is described later in this section.

DISTILLATION FURNACES.—The type of distillation furnace that is most economical depends greatly upon the kind and cost of the fuel that is available. In Europe, where coal is dear, the tendency of the last 10 years has been toward the introduction of Siemens regenerative furnaces. In Upper Silesia, the number of them at the older works has been increased, and the latest works, *i.e.*, the Bernhardihütte (1897) and the Florahütte (1900) have nothing but them. In Bel-

[2] United States Patent No. 691,112, Jan. 14, 1902.

gium the same tendency is manifested, the old furnaces that have been lately torn down at some of the works there having been replaced by Siemens massives with 240 large retorts. Such furnaces are now in use at Overpelt, Prayon and Engis. This is rather a reversal of opinion, because the Siemens system was early tried with the Belgian type of furnace and did not find favor. In the United States, where coal is generally very cheap, there is less incentive to economy in its use, although gas-firing may be advantageous in other respects. Siemens furnaces were built about 1880 at Rich Hill, Mo., Pittsburg, Kan., and Peru, Ill. The last is the only place where they are in use in the West at present. At Lasalle gas-fired furnaces, with partial recuperation of heat by means of stoves and by the generation of steam for power, have been employed for a long time. In the natural gas fields, so long as the supply of that wonderful fuel continues plentiful and cheap, there is no inducement to build expensive, heat-recuperative furnaces.

Iola Furnace.—The Iola smelters have settled upon a type of forced draft distillation furnace, which was originally adapted from the long furnaces employed at Lasalle, Ill.; after many vicissitudes and reconstructions, it has been modified so as to give satisfactory results with natural gas firing. At Cherryvale alone furnaces operated by natural draft are employed, following the type adopted in the Indiana gas field, but better designed and more substantially constructed. The Indiana type was tried experimentally at Iola, but has been discarded in favor of the forced draft furnace, or "blow" furnace, as it is commonly called.

The distillation furnaces now commonly in use at Iola comprise from 600 to 660 retorts, arranged in five rows of 60 to 66 each per side. The introduction of any portion of the gas through the end wall of the furnace has been discontinued, and the entire supply is now fed in through ports in the alternate pillars of the working sides of the furnace, the gas being brought down through branch pipes from the mains extending along the furnace for the full length of each working side. The omission of four tiers of retorts at one end of the furnace (in order to afford the gas and air formerly introduced at that end of the furnace an ample opportunity for mixture before reaching the retorts) has also been abandoned, and in those furnaces previously constructed in that manner the former open space is now occupied by additional retorts, wherefore a furnace that used to contain only 620 retorts now has 660. The old furnaces have also been generally repiped, giving them a larger gas supply, a better distribution of gas and better means of regulating its influx, together with that of the air for its combustion, and consequently a better control of the temperature. The result of these improvements has been a complete elimination of the old trouble of soot deposition, which was, of course, due simply to a deficiency in air supply or to imperfect admixture of the air and gas, while a uniform temperature throughout nearly the whole length of the furnace is attained and can be maintained as desired, of course with a beneficial effect upon the yield of metal obtained from the ore. Not less in importance is the better systemization of the labor in distillation, which has enabled the maneuver, *i.e.*, the discharging and recharging of the retorts and the accessory processes, to be performed within the customary limit of five hours, or in but little excess over that time.

The physical construction of the furnaces has also been improved, many of the older ones with entirely too light walls and imperfect bracing having been torn down and replaced by furnaces of more substantial and better ironed masonry. This has led naturally to an increased length of furnace campaign. It is probably still too early to determine what will be the average duration of furnace campaign at Iola, inasmuch as gas smelting there is not yet more than five years old and it is only within the last two years that the practice has definitely crystallized, but there seems to be no reason why the average should not exceed two years and with good construction in the first place and subsequent careful attention it may be fully three years. The form of furnace with a single, large, light and airy ash-tunnel is generally adopted, none but the furnaces at La Harpe having two tunnels, but the chimneys instead of being built in connection with the end wall of the furnace, resting on the arch of the ash-tunnel, as was the case of some of the earlier furnaces, are now set a few feet in advance of the end wall and offset from the prolongation of the center lines of the combustion chambers, so that they stand on a solid foundation independent of the furnace proper and at the same time leave the ash-tunnel clear, connection between the combustion chambers and their respective chimneys (two per block) being made by short horizontal flues. Another detail in which there has been a change is the removal of the gas regulator to a point 40 or 50 ft. outside of the furnace house, the advisability of this change having been indicated by the explosion of a regulator in one case, ignition of the escaping gas and destruction of the furnace and house; formerly the regulators were frequently contained in a small lean-to directly connected with the furnace house.

The furnace houses are designed after the same general type throughout the district. This is a long frame building with a simple pitch-roof supported by posts (no trusses) which are disposed in such a way as to leave an ample clear space in front of the furnace. The distance from the working faces of the furnace to the sides of the building is sufficient to enable work to be done with comparative comfort notwithstanding the intense radiation of heat from the long furnaces. The floors of the buildings are paved with brick and the ore is brought in by means of large charging cars on tracks extending in front of the furnace on each side. Movable shields to aid and protect the men in working the furnace are used at all the works without exception. In the present practice the blowers, which are of the ordinary fan type, are situated in the main engine house. Each works is provided with at least a duplicate installation and it is the common practice to run one fan by day and the other by night. In large works this arrangement involves the transmission of the air a long distance in order to reach the more remote furnaces.

Although the furnace of the dimensions described above has become the Iola standard, the Lanyon Zinc Co. experimented during 1901 with some furnaces of the same type, but with only 400 retorts, these being arranged in five rows of 40 each per side. Two furnaces of that size are installed end to end, with proper space between them, in a single house, giving thereby 800 retorts per house. The fact that the Lanyon Zinc Co. has been building some additional furnaces of the same dimensions indicates that the result of the first ones

were satisfactory. It is naturally to be expected that modifications in the number of retorts per furnace and their arrangement will be made from time to time, but there seems to be little probability that a further change from the Iola type of furnace as a type will have to be made so long as the supply of natural gas continues to be ample.

The standard Iola furnace distils per 24 hours per massive from 24,000 to 26,000 lb. of ore, with which is mixed 40 to 50% of coke and lean coal as reduction material. The furnace crew per massive consists of two firemen, who work 12-hour shifts, four chargers, six men in front of the car, four men behind the car and two condenser cleaners; on the night shift there are two metal drawers and one stuffer and metal piler. This arrangement obtains in all of the works of the district, with slight modifications; for example in some works there are only two firemen per two blocks. The maneuver is begun about 5 A.M. and is completed about 10:30 A.M.

Ferraris Furnace.—This is a new type of distillation furnace, invented by Erminio Ferraris, which has lately been introduced at the works of the Società di Monteponi, in Sardinia, where it has given very successful results. It is gas-fired and heat-recuperative, but has regenerative chambers for air alone, the gas being delivered already hot from the generator (which should be therefore set as near the furnace as is convenient) and being further preheated only by circulation through flues in the middle longitudinal wall, which divides the furnace into two separate combustion chambers. The movement of the burning gas through the combustion chambers is longitudinal, but the direction of the current is periodically reversed, wherefore there is no cold end. Beneath each combustion chamber there are two heat-recuperating chambers, filled with hollow brick, standard fire brick, or tiling, in such a way as to form numerous horizontal, parallel flues, which are divided into two groups by a horizontal partition, compelling the products of combustion entering at one end of the recuperative chamber from the corresponding end of the combustion chamber to traverse horizontally through the recuperative chamber, first through the upper division toward the middle of the furnace and thence backward through the lower division to the end, where communication is made with a longitudinal flue leading to a main flue which leads off from the middle of the furnace to the chimney. The gas from the producer, situated at one side of the furnace house, is delivered through a properly lined pipe to the center of the furnace overhead, whence it is directed, by changing the position of a valve, alternately to one end of the furnace or the other, passing through the flues in the middle wall. It enters the combustion chamber through ports below the lowest row of retorts, which ports are provided at intervals up to a line midway and transversely through the combustion chambers, so that the gas, instead of merely entering at the end, is distributed through the latter, thus insuring complete combustion of the gas by gradual admixture with air and a proper heat in the middle of the combustion chamber, which might otherwise average a little cooler than the ends. In the flue leading to the chimney there is a reversing valve to change the current of the products of combustion, which valve is connected with the gas valve over the furnace, so that the entire system will be operated together.

In operation the gas entering at one end of the furnace meets the hot air issuing from the recuperative chambers corresponding to that end. The burning gas passes horizontally toward the other end of the combustion chambers, enveloping the retorts on the way, and thence escapes into the recuperative chambers corresponding to that end, traveling horizontally through their flues and making a return pass before reaching the large flue leading to the chimney. In the meanwhile the air for the combustion of the gas is entering through the flues of the opposite pair of recuperators. At the end of the proper interval the direction of the currents of air and gas is reversed.

This furnace, which is designed on thoroughly scientific principles, has the important advantages of maintaining an equable temperature throughout a great length, and at the same time permitting the installation of a heat recuperative system of high efficiency. The appropriation of the entire available space under the combustion chambers to regenerative chambers for air alone simplifies the construction as compared with Siemens furnaces, in which heat is recuperated through the media of both gas and air. With regenerators for air alone there is no trouble from gas leakages and the hot brick of the flues is subjected only to the strongly cooling action of cold air. The gas, which is delivered to the furnace from above, arrives with much of the heat of the primary combustion in the producer, and is further heated during its circulation through the flues in the middle longitudinal wall; the heat that is acquired in the latter manner is no actual gain, however, inasmuch as it is abstracted by conduction and radiation from the combustion chambers to which it is immediately returned as caloric of the gas. The furnaces at Monteponi have 180 large retorts per massive and smelt from 6,000 to 7,000 kg. (13,228 to 15,432 lb.) of calcined ore per 24 hours.

Neureuther Furnace.—Charles F. Neureuther, of Peru, Ill., patented a modification of the Siemens regenerative Belgian distillation furnace, in which the air and gas are partially discharged half way up in the combustion chamber by means of vertical ducts and corresponding ports in the middle longitudinal wall. In the Siemens regenerative Belgian furnaces built heretofore in the United States the gas and air have been discharged under the lowest row of retorts; Neureuther states that with that method of heating the retorts of the upper rows have not been so highly heated as those of the lower rows, with the result that the ore charged into the upper retorts has required a longer time for distillation and the residues have been richer in zinc than they ought to be, and claims that by introducing the gas and air at different points in the height of the combustion chamber a more uniform temperature is obtained. He claims also that the capacity of the furnace is increased and that it is practicable to install at least one more row of retorts than in the older furnaces. The building of ducts in the middle of the longitudinal wall necessitates that the latter be made thicker at the bottom, on which account the retorts of the lowest two rows are made necessarily shorter than those of the upper rows.[3]

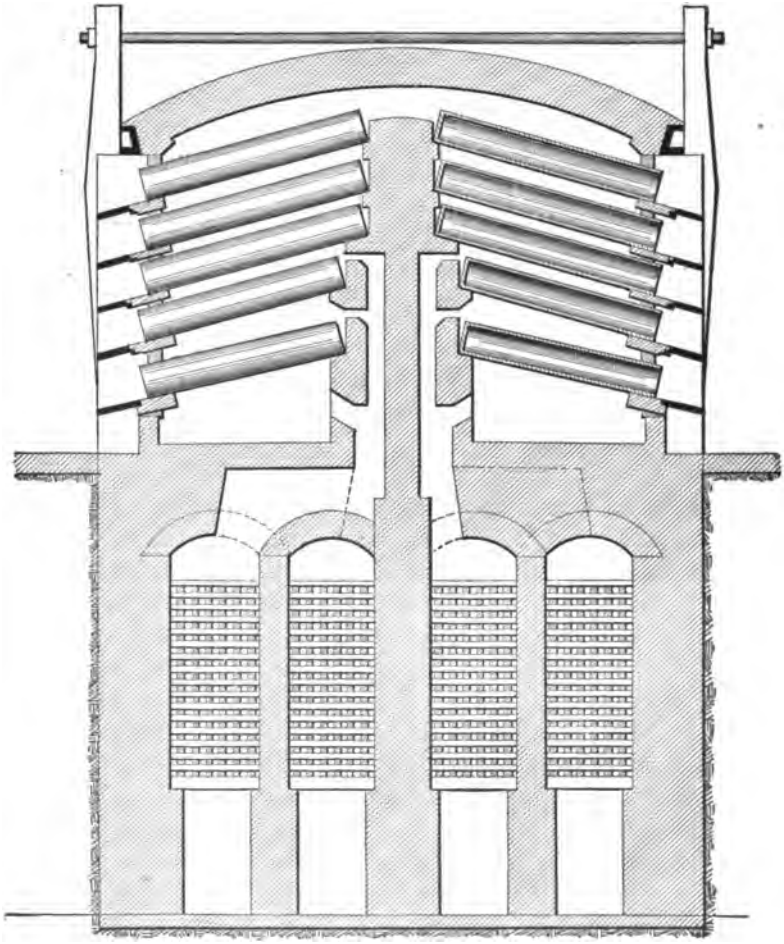
NON-CORROSIVE RETORT LINING.—An interesting development of 1901 was the practical application of the Sadtler retorts[4] at the works of the Midland

[3] United States Patent No. 666,390, Jan. 22, 1901.

[4] *Engineering and Mining Journal*, Sept. 29, 1900; THE MINERAL INDUSTRY, Vol. IX., p. 668.

Smelting Co., at Bruce, Kan., which were leased by the owners of the patents for the purpose of demonstration. Operations were begun June 10, since which time ore high in lead and iron from Colorado, together with some ore high in iron from the Joplin district, has been regularly smelted, apparently with successful results. I am informed that at least one other smelter in Kansas intends to give the Sadtler retorts a trial in 1902.

It is reported that a slight difficulty was experienced because of cracks some-



NEUREUTHER-SIEMENS REGENERATIVE FURNACE.

times occurring in the lining of these retorts, which would permit the slag to corrode through the retort and dripping down upon those of the lower ranks would corrode them from the outside. To obviate that difficulty the upper outside of the retorts has been coated in the same way as the inside, so that if a crack should occur in the lining of a retort in the upper ranks those situated below it will not suffer.

QUALITY OF SPELTER.—The quality of the spelter produced is a matter which

receives careful attention by the Kansas smelters, particularly in order to meet the requirements of the brass trade. Some of the smelters keep apart the first drawing of metal from the condensers and cast it in 50-lb. slabs which are sold under the names of "extra select," "brass special," or some other particular brand. Metal of that class contains but little more than 0·5% lead and is generally safely within the iron limit. The ordinary product of the Iola smelters is marketed in the form of slabs weighing from 65 to 67 lb., or roughly 30 slabs to the ton.

E. Herter, of Beuthen, Upper Silesia, patented an apparatus for separating lead from spelter simultaneously with the drawing of the latter from the condensers of the distillation furnace. The molten spelter is collected in a kettle lined with refractory material, which has a lip on one side and at the bottom an outlet hole fitted with a goose-neck or other suitable device for drawing off the lead settled from the spelter. The kettle is surrounded by a jacket, which is arranged with fire-bars at the bottom, and the annular space between the kettle and the jacket is kept filled with glowing coke. A cover is provided to close the annular division at the top. The whole apparatus is supported on trunnions at the end of a horizontal arm which is mounted on a movable carriage. The zinc is allowed to remain in the kettle at any desired temperature for as long a time as may be necessary to permit separation of the lead.[5]

MISCELLANEOUS PROPOSALS.—Following are some of the miscellaneous proposals for the recovery of zinc from its ores, which have been referred to in the literature of the year.

Reduction of Blende by Calcium Carbide.—L. M. Bullier patented a process for the metallurgical treatment of sulphide ores by smelting with calcium carbide. The ore, with or without a preliminary roasting, is fused at a clear red heat with granuated calcium carbide and a suitable flux for about one hour, by which means copper and certain other metals may be separated in what is claimed to be an entirely novel manner. In treating the sulphides of volatile metals a closed apparatus is used.[6]

Electric Smelting.—Casaretti and Bertani patented a process for the production of zinc by smelting in an electric furnace, which is being worked by the Società Elettro-metallurgica Lombarda. It is claimed that 1 kg. zinc is produced per 2 H.P. hours, the quantity of coal consumed in each furnace being 15 kg. per 100 kg. of ore.[7]

RECOVERY OF ZINC FROM WASTE PRODUCTS.—J. Richards lately described some methods used practically for the recovery of zinc from galvanized iron scrap, and other waste material, in connection with the recovery of tin from tin-plate scrap, which are of much interest.[8]

Tin and Galvanized Iron Scrap.—The method employed for the treatment of this material consisted in immersing the tin-plate scrap in hydrochloric acid until the tin was dissolved, followed by an immersion in water, then in water with a little lime, then again in water, and finally for a moment in a solution of copper sulphate. The vats containing the various solutions were arranged in

[5] British Patent No. 8,175, April 20, 1901.
[6] British Patent No. 9,046, of 1900.
[7] L. Belloc, *Elettricità*, Milan, XIX., 593; *Science Abstracts*, 1901, IV., 1, 74.
[8] *Journal of the Franklin Institute*, CLI., 445-455; CLII., 59-63.

a semicircle, commanded by a central crane; they were 6 ft. in diameter, 6 ft. in depth, and were sunk in the ground. The scrap was packed in a wooden cage, holding 200 lb., which was handled with the aid of the crane. The object of dipping the cleaned scrap in the solution of copper sulphate was to deposit upon it a thin coating of copper in order to protect the iron from rust, until after consolidation under a drop-press it could be reheated and forged into blooms. The tin was recovered from the chloride solution by dipping galvanized iron scrap in it, whereby metallic tin was precipitated by the zinc dissolved from the iron, zinc chloride being formed by the reaction. The precipitated tin was then collected and remelted, and the zinc chloride was sold for use as a disinfectant. About 600 lb. of tin were recovered from 10 tons of scrap. The cleansed iron sold for $10 per ton.

Waste Products from Galvanizing.—Sal ammoniac skimmings from the surface of the zinc bath used in galvanizing, which consist chiefly of zinc oxide dissolved in ammonium chloride and double chloride of zinc and ammonium, were leached with hot water and steam, whereby the chlorides were dissolved. They could be recovered for further use as galvanizing flux by boiling down the solutions and crystallizing them out. The residuum from the lixiviation, consisting of zinc oxide, dirt and shots of zinc, was tumbled in a revolving barrel whereby the shots of metal were cleaned so that they could be remelted on the top of a pot of molten zinc. The zinc oxide which became crushed to a powder was marketable at $30 per ton with manufacturers of zinc paint. The average yield of such skimmings from galvanizing was 20% spelter, 30% ammonium and zinc chlorides, 35% zinc oxide and 15% iron scale and dirt.

Zinc Dross.—The zinc-iron alloy, known as zinc dross, which accumulates at the bottom of the galvanizing pots, was treated by melting and introducing into the molten metal (below the surface thereof) a mixture of sulphur, potatoes and leather scrap. After about 15 minutes, action having been completed, a little aluminum was introduced in order to break up dissolved oxides. After permitting to stand for a short time, pure metal could be ladled off, most of the impurities of the dross remaining at the bottom of the pot. A sample of 40 carloads of spelter obtained in this way assayed 98·35% Zn, 1·5 Pb and 0·15% Fe. Spelter refined a second time by the same process contained from 99 to 99·75% Zn, the only impurity being lead. A third refining failed to raise the percentage of zinc higher than 99·85. Scrap zinc could be treated in the same way. The aluminum was most successfully introduced in the form of an alloy containing 98% Zn and 2% Al.

Zinky Lead.—The zinky lead which collects at the bottom of galvanizing baths was treated by remelting in a wide pot at a temperature only just above the melting point of lead. An iron ring, 2 ft. in diameter and 6 in. in depth, was placed on the surface of the metal, and the zinc was skimmed off within the ring as fast as it rose to the top in a pasty condition. The lead still contained about 2% Zn after this treatment; a further elimination of the zinc would be of course a simple matter by the ordinary refining process, which is employed in connection with the desilverization of lead. The impure lead found a ready market, however, for the manufacture of weights, counterbalances and for use as ballast, etc.

ZINC OXIDE.—One of the most important recent developments in the American zinc industry has been the remarkable increase in the production of zinc oxide. It is said that this has been partly absorbed by an increased consumption in the rubber trade, zinc oxide being an important ingredient in the compounding of rubber; it has partly been exported, there being a growing foreign trade in the American product; but notwithstanding those demands it must have gained great headway in the domestic paint trade in competition with the other white pigments, especially white lead. The merits of zinc white as a pigment were summarized by Maximilian Toch in a paper recently read before the New York Section of the Society of Chemical Industry.[9] He stated that the consumption of white lead is decreasing and that it should not be used alone. The specifications of the United States Lighthouse Department demand 75% of zinc oxide and 25% of white lead. Zinc white mixes well with other pigments, particularly with white lead. Zinc oxide made directly from ore is more durable than that made by burning spelter, and on a very large surface the difference in whiteness is soon apparent. Zinc oxide as the drying progresses becomes very hard and brittle, this being more the case with oxide made from spelter than with that made directly from ore. This is overcome by treating the linseed oil with 0·33% of litharge before mixing with the zinc white, a flexible drying paint being thus produced, which is essential in the manufacture of oilcloth. Zinc oxide is not affected by hydrogen sulphide, which gives it a superior advantage for the painting of the interiors of buildings. It is less absorbent than other paints, and can be washed. On outside walls it withstands well the action of the atmosphere when used to the extent of 50% mixed with white lead and barium sulphate.

A new plant for the manufacture of zinc white was erected at Joplin, Mo., in 1901 by the Renfrow Paint Co. The raw material that is to be employed is a zinc carbonate, assaying about 37% Zn, which is obtained from what is supposed to be a large deposit at West Plains, Mo.

W. B. Middleton patented a special furnace for the direct production of zinc white from ore. This furnace is of the reverberatory type, but is without a fire-bridge and has a fire-box about 3 ft. deep. The fire-box is filled with fuel, and a charge of roasted blende, or calamine, is put on the hearth. When it becomes hot it is raked off the hearth on to the top of the incandescent fuel, and a fresh charge is put into the furnace, more fuel being thrown into the fire-box at the same time. As soon as the hot ore reaches the fuel, zinc fumes are evolved and travel over the hearth into a suitable condensing chamber. The fire-bars of the furnace are carried loosely on notched bearers, beyond which their ends project, so that they can be turned by means of levers in order to break up and remove the clinker.[10]

ELECTROGALVANIZING.—The use of electrogalvanizing for the production of boiler tubes and for the coating of torpedo plates and torpedo-boat fitting has been increased by the recent construction of an electrogalvanizing plant for Messrs. John Cockerill & Co., of Seraing, near Antwerp, Belgium. The con-

[9] *Journal of the Society of Chemical Industry*, Jan. 31, 1902, p. 103.
[10] British Patent No. 12,274, June 15, 1901.

struction and working of the plant is similar to the one built in 1900 for the German Shipbuilding & Engineering Co., at Tegel, near Berlin, a description of which appeared in THE MINERAL INDUSTRY, Vol. IX., pp. 683-685.

TREATMENT OF MIXED SULPHIDE ORES.—The mixed sulphide ores of Leadville, Colo., have been treated on a large scale by careful separation of their minerals with the aid of Wilfley and similar tables. The galena concentrate finds a ready market with the lead smelters and the blende concentrate has been of such a character that the zinc smelters would take it at a low price, generally $6@$7 per 2,000 lb. f. o. b. Leadville. The larger part of the Leadville product, which probably averages about 45% Zn, 6% Pb and 10% Fe, has been exported to Europe, via Galveston, the freight from Leadville to Swansea and Antwerp being about $9·50 per 2,000 lb. In 1900 the total production of zinc ore in Colorado, according to H. A. Lee, commissioner of mines, was 77,984 tons, averaging 42% Zn; this doubtless included all the ore that was used for the manufacture of zinc white, and zinc-lead pigment, as well as for spelter. In 1901, Leadville produced 23,261 tons of zinc ore. In addition to Leadville, shipments of zinc ore are made from Silver Plume, Montezuma, Creede, Rico, and elsewhere in Colorado.

The fact that Colorado blende contains iron in its composition makes it susceptible to the intense magnetic influence of the Wetherill machines and enables it to be separated from the intermixed galena and pyrite, which are both absolutely non-magnetic. Experiments have demonstrated that this is a process which will be commercially successful, and the Colorado Zinc Ore Co. and the New Jersey Zinc Co. have been lately erecting magnetic separating plants at Denver and Cañon City respectively, which ought to be in operation in 1902. The indications point toward the production of an ore of about the same percentage of iron as that which the present concentrating mills are furnishing, but several units higher in zinc and lower in lead. A magnetic separating plant is said to be already in operation at Rico.

The treatment of mixed sulphide ores by the Sadtler process of distillation has been referred to previously in this review. Some of the new proposals of a hydrometallurgical and electro-metallurgical nature are summarized in the following paragraphs.

Bechi.—Guy de Bechi, of Paris, France, patented the roasting of zinkiferous sulphide ores with admixture of from 15 to 30% of silica, whereby it is claimed the zinc is rendered more completely soluble in acids than when the ore is roasted without such admixture.[11]

Clancy & Marsland.—J. C. Clancy and L. W. Marsland, both of Sydney, N. S. W., are the inventors of a process which is being exploited by the Clancy-Marsland Sulphide Process Co., Ltd., of Sydney, and has been tried experimentally at that place. The fundamental feature of the process, which is described with numerous modifications, is the admixture with the ore of lead sulphate in molecular proportion and heating, whereby it is claimed that the ore is decomposed in a manner analogous to that which takes place in the roast-reaction method of smelting galena. It is claimed that in this way the zinc is rendered

[11] British Patent No. 985, Jan. 16, 1900; *Journal of the Society of Chemical Industry*, Jan. 31, 1901, p. 47.

completely soluble in sulphuric acid, while the desulphurization of the ore is completed in so short a time as 30 minutes. The reaction is effected in a reverberatory or muffle furnace, either below or above the temperature at which lead will be volatilized. In the former case the desulphurized ore is treated with sulphuric acid in order to obtain soluble zinc sulphate and insoluble lead sulphate; in the latter, the gas from the furnace, laden with zinc-lead fume, is passed into dilute sulphuric acid; in either case the results finally accomplished are the same. The lead is obtained as sulphate, of which the necessary proportion for the decomposition of more ore is reserved, while the remainder is smelted for metal. The zinc is obtained as a solution of its sulphate, which is evaporated to dryness and heated to the temperature of decomposition, in order to obtain zinc oxide as the final product. The sulphurous and sulphuric gases evolved during different stages of the process are converted into sulphuric acid. The process in its numerous modifications is described in a pamphlet published by the company which is promoting it, and in numerous patent specifications.[12]

Davis.—G. E. Davis and A. R. Davis, of Manchester, England, patented a process for the treatment of mixed sulphide ores by digestion with dilute nitric acid, a preliminary roasting being unnecessary, since nitric acid decomposes most sulphides. Zinc, lead and iron go into solution as nitrates, and all but the zinc can be precipitated by addition of zinc oxide, which if properly regulated will enable a fractional separation of the metals to be made and the lead to be recovered separately. Lead is precipitated from the mixed solution of zinc and lead nitrates by adding zinc oxide and passing in carbonic acid gas, whereby lead carbonate is thrown down, zinc replacing lead in the solution. It is preferred to conduct the process in two stages, less than the theoretical quantity of zinc oxide, mixed with the lead precipitate of a previous second stage operation, being used in the first; in the second stage an excess of zinc oxide is employed.[13] The purified solution of zinc nitrate is then evaporated to about 1·5 sp. gr. and furnaced for the production of zinc oxide and gaseous nitrogen compounds. The latter together with the nitrous fumes from the original treatment of the raw ore are recovered as nitric acid, available for attacking a fresh lot of ore. The residue from the digestion with nitric acid contains silica, sulphur and lead sulphate, together with gold and silver. The nitric acid used for attacking the ore may be diluted with weak zinc nitrate solution so as to obtain a stronger solution for the ultimate evaporation.[14]

The Messrs. Davis also proposed to treat sulphide ore by digestion with hydrochloric acid, saturating any free acid in the liquor therefrom with zinc oxide, oxidizing any iron therein to the ferric state, precipitating ferric hydroxide by means of zinc oxide, and then precipitating silver from the solution as iodide by the Claudet process. After removal of the lead by means of zinc oxide and carbonic acid gas as described in another patent[15] the residual solution of zinc chloride is to be concentrated for recovery of that salt, or the zinc is to be pre-

[12] Among others, British Patents Nos. 4,039 and 9,503, of 1901.
[13] British Patent No. 253, Jan. 4, 1900.
[14] British Patent No. 710, Jan. 11, 1900.

cipitated therefrom as oxide. The residuum from the original lixiviation with hydrochloric acid is to be treated with hot water to dissolve out the lead chloride therein, which may then be recovered as such, or as carbonate. The silver may be extracted by means of ammonium or sodium thiosulphate, and the residue then remaining may be roasted to convert undecomposed zinc sulphide into oxide for use in saturating the free acid in the original solution from the first ore treatment. In digesting the ore with hydrochloric acid, hydrogen sulphide is evolved which may be burned to sulphurous anhydride for the manufacture of sulphuric acid or from which sulphur may be recovered by the Claus method. A modification of this process consists in the treatment of only three-fourths of the ore with hydrochloric acid, the lead sulphide being more readily attacked than the zinc, and of roasting the remaining fourth into a crude zinc oxide which may be used for the purpose of saturating the free acid as before mentioned.[15]

Ellershausen.—F. Ellershausen took out a further patent[16] on the process which has been experimented with upon a large scale at Angoulême in France and was referred to in THE MINERAL INDUSTRY, Vol. IX., p. 688.

Ferraris.—Erminio Ferraris patented a process for the treatment of mixed sulphide ore, wherein the ore is heated with concentrated sulphuric acid in a furnace, by which operation there are produced metallic sulphates, sulphurous acid, water and sulphur. The sulphur is burned and the whole of the sulphurous acid is then converted into sulphuric acid. The ore withdrawn from the furnace is leached with water to dissolve the soluble sulphates. From the solution, the copper and the iron present as ferric sulphate are precipitated by means of zinc oxide. The iron present as ferrous sulphate is then precipitated by means of zinc oxide and compressed air injected into the hot solution. Zinc sulphate is to be recovered from the purified solution by boiling down. In order to obtain zinc oxide, for the recovery of metallic zinc, it is proposed to heat the zinc sulphate with admixture of carbon.[17]

Ganelin.—Solomon Ganelin, of Berlin, Germany, proposed to introduce zinc-lead compounds, in the form of oxides, into molten zinc chloride and electrolyze for recovery of the metals.[18]

Kellner.—Carl Kellner, of Vienna, Austria, patented the process of converting the zinc compounds of roasted ore into sulphites, changing to sulphates by a suitable oxidizing agent, and adding to the solution an alkaline earth chloride, thereby precipitating the corresponding sulphate and affording a solution of zinc chloride from which the metal may be recovered.[19]

Swinburne and Ashcroft.—The so-called Phœnix process, invented by James Swinburne and Edgar A. Ashcroft, was described by the latter in a paper read before the Institution of Mining and Metallurgy, London, June 19, 1901. It was stated that although the process has not yet been applied on a commercial scale, considerable quantities of ore have been treated by it and many tons of zinc and lead have been extracted. This process has previously been described in THE

[15] British Patent No. 2,089, Feb. 1, 1900.
[16] British Patent No. 488, Jan. 8, 1900; *Journal of the Society of Chemical Industry*, Jan. 31, 1901, p. 47.
[17] British Patent No. 12,349, June 17, 1901.
[18] British Patent No. 24,469, of 1899.
[19] United States Patent No. 690,295.

MINERAL INDUSTRY, especially Vol. IX., p. 692. The reactions involved in it are so novel and the problem of the electrolysis of molten zinc chloride has been worked out in so interesting a manner that it appears to be worth while to present a rather extended abstract of Mr. Ashcroft's paper.

As described by Mr. Ashcroft the principles which characterize the process are as follows:—

I. Displacement of sulphur (or other elements) from combination with metals in the ore, by means of chlorine gas in the dry way.

II. Substitution of one metal for another in a mixture of fused chlorides by precipitation with a metal, or by the fractional electrolysis of the mixed chlorides in a fused state.

III. Separation of siliceous gangue from the final metallic chloride by settling and decantation, and washing the residue with water (or alternatively by distillation of the chloride from the residue).

IV. Purifying the chloride, boiling down the wash solutions, if any, and preparing the chloride for electrolysis.

V. Electrolytic decomposition of the final chloride for the recovery of its metal and chlorine, the latter being recovered and collected under a suitable pressure.

The decomposition of a sulphide ore by chlorine is represented by the following equation:—

$$M + Cl_n = M\,Cl_n + S.$$

If the ore be an oxide, instead of a sulphide, the reaction is expressed as follows:—

$$MO + Cl_n = M\,Cl_n + O.$$

These reactions are claimed by the inventors to be an original discovery. It has heretofore been supposed that when a metallic sulphide was treated with chlorine gas, both the corresponding metallic chloride and sulphur monochloride would be formed. This would occasion large losses of chlorine and involve other difficulties which would render the process economically impracticable. Messrs. Swinburne and Ashcroft claim to have proved, however, that the formation of sulphur monochloride takes place only at low temperatures, and instead of that product being a necessary result of the reaction between chlorine gas and the metallic sulphide, liquid sulphur monochloride can be employed for the decomposition of such sulphides, in which case both the sulphur of the ore and that of the sulphur monochloride is recovered; in fact sulphur monochloride is only formed by the action of excess of chlorine on the liberated sulphur at low temperatures. The critical temperature at which sulphur monochloride ceases to form when metallic sulphides are treated with chlorine gas is approximately 600°C., which is also approximately the lowest temperature at which chlorine gas ceases to attack actively the sulphides. It attacks them slowly, however, at much lower temperatures.

The method adopted by Messrs. Swinburne and Ashcroft for decomposing the ore is to employ a vessel of large size, called a converter, into which is introduced, at a suitable temperature, an emulsion of the sulphides under treatment with fused zinc chloride. Chlorine gas is then injected at the bottom and ore is fed in

at the top, the resulting sulphur, which is vaporized at any temperature above 450°C., being carried away into a condensing chamber or flue and there collected. Decomposition is rapid and complete, and the heat set free in the reaction maintains the proper temperature. The addition of ore to the converter and the blowing in of chlorine gas is continued until the apparatus is full of fused chlorides in the molten state, in which the siliceous gangue remains suspended. The greater part of the contents of the converter is then tapped off through a hole, or decanted by tipping the converter; that which remains holds sufficient heat to enable the process to be resumed by blowing in more gas and putting in more ore. The process is completely under control, and inasmuch as the reaction is strongly exothermic the heat can be regulated, and maintained at the most suitable temperature, by altering the rate of working. It is possible by forcing the latter to distil off the chlorides from the converter. It is unnecessary to crush the ore very fine, comparatively large grains being readily acted upon. An apparatus of small size puts through an astonishing quantity of ore and works with great facility. The sulphur comes off as vapor which is easily condensed, and nothing escapes from the condensing chamber except such small quantities of impurities as may have been mixed with the chlorine gas in the first instance, and any sulphurous anhydride gas corresponding to sulphur burned by air accidentally admitted. The fused chlorides run from the converter more freely than the most fluid of slags.

In the treatment of 1,000 kg. of ore, assaying 29% Pb, 26% Zn, 21% S, 5% Fe, 2% Mn, 17% gangue, and 19 oz. silver per ton, there was consumed 470 kg. of chlorine gas. The experiment lasted 12 hours. The average temperature was 650°C. Four pours were made. The condensed sulphur weighed 100 kg.; the remainder of the sulphur in the ore was burned to sulphurous anhydride and escaped. The condensed sulphur was readily purified, associated chlorides being recovered by washing with water. If a little acid be present in the wash water, the sulphur assumes the brilliant yellow color of pure brimstone. All of the gangue and 92% of the chlorides remained in the converter; 8% of the chlorides (consisting mainly of iron and zinc chlorides) was carried away with escaping sulphur vapor and was found in the condenser. The quantity of fused chlorides obtained was 1,260 kg., which assayed as follows: 23% Pb, 21% Zn, 4% Fe, 1·5% Mn, 37% Cl, 13·5% gangue, and 15·5 oz. silver per ton. This represented a conversion of the entire metallic contents of the ore into chlorides, except the iron and manganese contents of the siliceous gangue which remained as silicates. The fused chlorides were free from sulphur.

The silver contained in the fused chlorides (and similarly gold if it be present) can be completely extracted by agitating the mixture with metallic lead, whereby rich bullion is produced which contains all the precious metals present. The reaction is said to be remarkably complete. If the chlorides contain antimony or copper, either lead or zinc may be used for their extraction. The copper is most easily obtained in alloy with excess of zinc as brass, owing to its high melting point. Metallic lead is extracted from the chlorides by means of metallic zinc, which operation consumes a considerable quantity of zinc, producing the equivalent of zinc chloride. The lead may be obtained quite free from zinc by

performing the operation in two stages at a low temperature (approximately 450°C.). Iron and manganese are removed from the converter mixture as oxides, either before or after the chlorides have been separated from the siliceous gangue, which is done by settling and decantation, by solution of the residual chlorides in water, and finally boiling down the pure solution in a suitable apparatus. After the recovery of the silver and lead by means of metallic zinc as described above, the only foreign element in a mixture of chlorides of the character shown by the analysis previously quoted, which would interfere with the electrolysis of zinc chloride is iron, and that metal is readily oxidized to ferric oxide in the converter by the application of a blast of air at a certain stage of the converter process. The suspended ferric oxide is afterward removed with the gangue matter. Manganese is quickly removed as dioxide by the same means, but inasmuch as it does not interfere in the electrolysis of fused zinc chloride its complete removal is not important, and it is eliminated only to prevent undue accumulation in cyclic working.

The following reactions are supposed to occur in removing iron and manganese:—

$$4FeCl_2 + 7O_2 + 4ZnS = 2Fe_2O_3 + 4ZnCl_2 + 4SO_2$$
$$MnCl_2 + 2O_2 + ZnS = MnO_2 + ZnCl_2 + SO_2.$$

In order to separate the heavy siliceous matter and the iron and manganese oxides from the zinc chloride, the latter is allowed to stand long enough to permit the impurities to settle, after which various quantities of pure zinc chloride can be decanted off. The residue may be distilled in fire-clay retorts, and the zinc chloride (which volatilizes at 720°C.) be collected, but a more convenient practice is thought to be washing the residue with water and boiling down the solution of zinc chloride until fused. The latter is the method which has been adopted in the experimental work.

The solutions are boiled down first in lead lined vessels, and finally in enameled iron pans, or in tank furnaces in which the solution is heated from above. In the boiling down process the chloride behaves much like caustic soda, frothing a little at the end and then settling down to tranquil fusion. Fused zinc chloride, when free from lead and other chlorides and water, is readily handled and dealt with in iron pots and with iron tools, which it does not attack. At temperatures below 400°C. it is fluid and does not fume in the air. The dehydration of the zinc chloride and elimination of the last traces of iron, lead and other impurities, which would contaminate the spelter or interfere with the electro-deposition, is effected by means of a short preliminary electrolysis with a cheap form of carbon anode, which is destroyed by the oxygen liberated. This preliminary treatment is carried out in a special form of vat arranged for easy removal of carbons and easy cleaning out. It affords a zinc chloride which is free from hydrogen, iron, and lead, and can be decomposed by electrolysis to the best advantage. The power consumed in this preliminary process need not exceed 10% of that required for the final decomposition of the zinc chloride. The vats are left open to the air inasmuch as no chlorine is evolved until the treatment is complete.

The final electrolysis of the zinc chloride is effected in a circular steel tank, 6 ft. in diameter, lined with 18 in. of ordinary Stourbridge fire brick, the inner courses of which are set in a special cement. The cathode in each tank is molten zinc weighing about one ton. Connection with it is made by means of a heavy steel block buried in the brick work and provided with five screwed, copper, tubular rods through which the current enters from the outside and through which free circulation of air can take place to prevent overheating. The anode consists of a removable cast-iron plate, lined on the under side with a special cement, from which hang 120 rods of hard carbon, 2·25 in. in diameter, in such a way that they are immersed about 6 in. in the electrolyte. It will be observed that zinc chloride is maintained in a molten condition by internal heating by the current. A vat of the above dimensions takes a current of from 3,000 to 4,000 amperes with from 4 to 4·5 volts at the terminals and produces nearly a ton of zinc per week.

The current efficiency of the process, after the preliminary electrolysis, is about 95%, which allows for all leakage, etc. The pressure efficiency is, however, much lower. The theoretical electromotive force required for the decomposition for zinc chloride is 2·2 volts. The normal working electromotive force is about double that. By especially coating the vat of the dimensions specified above and conserving the heat, it is possible to work at 2,500 amperes, at which low current density, when the same gap is preserved between the carbons and the zinc, the pressure will fall to 3·5 volts. Ashcroft considers that with large units (say 10,000 amperes) a working pressure of three volts or even less might be obtained, inasmuch as the heat is more easily conserved in a large than in a small apparatus. In the latter case the watt efficiency would be 69·7%; or 60% after making allowance for the preliminary electrolysis. In the experimental work so far an electromotive force of four volts has been employed and the watt efficiency has been only 40%.

The molten zinc is tapped directly into molds, by removing a carbon plug, and fresh zinc chloride is poured into the vat by means of a crane and a tipping-ladle. The labor required for attendance to the vats is comparatively small, the difficulties accompanying the collection of the zinc in solid form and remelting it when a solution is decomposed being entirely obviated. The brick lining of the vats is not attacked; at least no injury was manifest after nine months' working. The carbon anodes last six months at least; when the preliminary treatment is properly carried out the action of pure zinc chloride on them appears to be *nil*, and since the anodes have seldom to be removed accidental breakages are not heavy. The quality of the spelter produced depends almost entirely upon the care taken in purifying the chloride. It appears to be not at all difficult to produce a product assaying 99·83% Zn, 0·15% Pb and 0·02% Fe.

The chlorine gas escaping from the electrolytic vats is drawn off into a holder by means of a small ebonite coated fan and motor. The vats are carefully closed to prevent as much as possible any dilution of the chlorine by air. The necessary holes through the cover are sealed by means of an earthenware tube, dipping into the molten chloride. The temperature of working is between 425 and 525°C., and should not vary beyond those limits for the best results. It is

found advantageous to the electrical conductivity to have sodium chloride, calcium chloride, etc., in admixture with the zinc chloride to the extent that the electrolyte will assay not more than 28% Zn, against 48·5% Zn for pure zinc chloride. These foreign chlorides are not decomposed in the presence of zinc chloride, and therefore do not require renewal.

The chlorine gas drawn from the holder is dried by causing it to pass through a tower packed with zinc chloride. For convenience in storage it is then liquefied. The handling of this gas was at first a troublesome problem, but it is claimed that satisfactory apparatus has now been devised. The gas is blown into the converter under a pressure of 50 lb. per sq. in.

Mr. Ashcroft estimates that an ore assaying 20% Pb, 20% Zn, 8% Fe + Mn, 18% S and 34% siliceous gangue, together with 12 oz. silver per ton (1,000 kg.) will yield 100% of its lead, zinc and silver and 55·5% of its sulphur. He estimates the cost of treatment per 1,000 kg. at £1 10s., not including power, but including repairs and renewals, administration and general expense, and interest and depreciation (reckoned at 10% of cost of plant); also replacement of zinc chloride lost in the process, which is estimated at 5%. With power costing £4 per E.H.P. per annum (a rate that is obtainable in the utilization of certain water powers) the cost per ton of ore would be 13s.; making the total cost of treatment £2 3s. = $10·50 per 1,000 kg. = $9·50 per 2,000 lb. A plant for the application of this process upon a manufacturing scale is to be erected at Weston Point, England.

Twyman.—T. Twyman, of Moortown, England, proposed to mix finely ground ore with a suitable proportion of zinc chloride and heat to just about, or a little below, visible red heat, with exclusion of air. Lead sulphide is thus converted into chloride, which can be leached from the ore, leaving all the zinc behind as sulphide. The residuum containing the zinc sulphide may be treated as a zinc ore in the ordinary manner; or it may be roasted to sulphate and oxide, and the sulphate having been dissolved out may be employed for precipitation of the lead from the chloride solution as sulphate, thus regenerating zinc chloride. As an alternative the mixture of sulphate and oxide of zinc may be used to precipitate a mixture of sulphate and oxide of lead.[20]

Worsey.—J. W. Worsey, of St. Helens, England, patented a process wherein mixed sulphide ore is roasted so as to contain between 8 and 16% S. The ore is then ground and mixed with about 2% of sodium nitrate and sufficient dilute sulphuric acid to combine with all the zinc present. The mixture is then heated in a water-tight vessel whence the fumes are carried off to a sulphuric acid chamber, more nitrate being added if necessary. The residue is roasted in a muffle furnace, with or without an oxidizing agent, and the soluble sulphates are then dissolved out with water containing sodium sulphate. The clear solution is precipitated with milk of lime, and the precipitate is heated in the presence of air in a furnace, the zinc being volatilized and collected in the form of oxide. The oxidizing agent to be added to the charge in the furnace during the roasting, in order to oxidize ferrous iron, is sodium nitrate, with or without lime.[21]

[20] British Patent No. 14,968, Aug. 23, 1900.

[21] British Patent No. 3,668, Feb. 24, 1900; United States Patent No. 678,210, July 9, 1901.

ANALYTICAL METHODS.—Some of the new analytical methods for the determination of zinc and cadmium, that were described in 1901, are briefly abstracted as follows:—

Ferrocyanide Method.—Dr. A. C. Langmuir stated at a meeting of the New York Section of the American Chemical Society, March 8, 1901, that he had found uranium acetate to be an unreliable indicator in the presence of small quantities of hydrochloric acid, a 3 or 4% solution of uranium nitrate being preferable. This recommendation is supported by the experience of other chemists.[22]

Precipitation of Zinc Hydroxide by means of Dimethylamine.—W. Herz has shown that the reaction between ammonia and zinc sulphate is incomplete, owing to the fact that the basicity of the ammonia is weakened by formation of ammonium sulphate. The stronger bases, methylamine and dimethylamine, precipitate the whole of the zinc in the form of hydroxide. The precipitated zinc hydroxide is soluble in excess of methylamine, but not so in the case of dimethylamine. The latter can be used therefore for the determination of zinc, and can afterward be recovered from the filtrate by making the latter alkaline and distilling.[23]

Titration with Sodium Thiosulphate.—P. Knaps described a method for the determination of zinc by means of iodine solution. Zinc sulphide, in the acetic acid solution in which it is ordinarily precipitated, is converted by iodine into zinc iodide and sulphur. If, however, more than 0·05 g. of zinc sulphide to 200 c.c. of water be present, the separated sulphur protects particles of it from the action of the iodine. This can be prevented by forming a precipitate, such as barium sulphate, in the liquid prior to the introduction of the hydrogen sulphide. Thus, from 10 to 20 c.c. of a solution of 150 g. of barium chloride in a liter, and the same quantity of sodium sulphate solution (200 g. per liter), are introduced, the zinc precipitated, and the excess of hydrogen sulphide removed by boiling. An excess of standard iodine solution is then added, the liquid is shaken for one or two minutes, and the excess of iodine is titrated with standard sodium thiosulphate solution. Ammonium salts do not interfere, and the results are accurate even in the presence of considerable quantities of manganese salts.[24]

Determination of Zinc as Phosphate.—P. H. Walker described a method for the volumetric determination of zinc which is a modification of that devised by Stolba for the determination of magnesium. To the zinc solution, which should contain ammonium chloride, a large excess of ammonia is added, followed by a large excess of sodium phosphate solution. Hydrochloric acid is then gradually added until, after stirring, the solution remains milky. It should then be heated to about 75°C., and the gradual addition of acid continued, with constant stirring, until nearly complete neutralization is attained. By this means the precipitate becomes crystalline; after standing five minutes it should be filtered off and washed with cold water until the washings show only a faint

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[22] *Vide* THE MINERAL INDUSTRY, IX., 675.
[23] *Zeitschrift fuer Anorganische Chemie*, XXVI., pp. 90-93; *Chemische Centralblatt*, I., vii., 868.
[24] *Chemiker Zeitung*, XXV., 539-540.

trace of chlorine. The filter paper and precipitate are then returned to the beaker in which the precipitation was carried out, an excess of standard acid is added, and the exact point of neutrality is determined by means of standard alkali, using methyl orange as indicator. The reaction which takes place is represented by the following equation:—

$$ZnNH_4PO_4 + H_2SO_4 = ZnSO_4 + NH_4H_2PO_4.$$

Calculation from the above equation shows that 1 c.c. of normal acid corresponds with 32·7 mg. of zinc.

The method gives good results. Since the zinc ammonium phosphate is not precipitated in presence of a large excess of ammonia, any magnesium present, which will be precipitated, may be removed by filtration, and the filtrate neutralized to throw down the zinc. Fairly good results are obtained by this method also in the presence of iron, calcium, and magnesium, but any manganese must be previously separated, best by means of nitric acid and potassium chlorate.[25]

Analysis of Spelter.—The following short method was described by Dr. A. C. Langmuir, in a paper read before the New York Section of the American Chemical Society, March 8, 1901: Cover the sample with water, add a few drops of platinum chloride, and then sufficient sulphuric acid to start a moderate rate of solution. After the zinc has dissolved, filter off the lead, dissolve the latter on the filter with nitric acid and convert to sulphate as usual. The solution of zinc may then be at once titrated for iron with permanganate solution, after which cadmium may be precipitated with hydrogen sulphide.

Estimation of Cadmium.—E. H. Miller and R. W. Page have recently investigated several methods for the quantitative determination of cadmium.[26] They found the electrolytic method to be very accurate if a large excess of potassium cyanide and the presence of other salts be avoided. The carbonate method is the most troublesome and the least accurate. A very accurate method is the precipitation of cadmium from a neutral solution (cold) by a large excess of di-ammonium hydrogen phosphate and either weighing the precipitate as $CdNH_4PO_4,H_2O$ on a tared filter (after drying at 100 to 103°C.), or dissolving it in dilute nitric acid and igniting to pyrophosphate.

The Cermak-Spirek Furnace for Calcining and Roasting Zinc Ores.

By Vincent Spirek.

This furnace was built for the Crown Spelter Co., Ponte di Nossa, Bergamo, Italy, and has been in successful operation since July, 1901. The furnace is of the Cermak-Spirek type having a capacity of from 10 to 12 tons per day. A thorough preheating of the flames is effected in the lower part, the flames entering by two openings (shown in Fig. 1) which are independent and can be controlled to suit the character of the material to be roasted, whether smithsonite or zinc blende. As will be seen from the drawings, the furnace is square in outline and rests upon bedplates supported by T rails. In the bedplates are gates through which the roasted ore may be discharged by means of the device

[25] *Journal of the American Chemical Society*, XXIII., vii., 468–470.
[26] *School of Mines Quarterly*, 1901, XXII., iv., 891–808.

shown in Figs. 2 and 3. The interior of the furnace is filled with sets of transverse tiles of V shape, the apex upward, and staggered so that the apex of each tile comes opposite the space between the edges of the two tiles in the layer next above. The ore rests upon the sides of these tiles, and gradually works down as the roasted material is withdrawn. The flames pass from the hearth into the channel *L* III., Fig. 2, which is also connected with the air entrances,

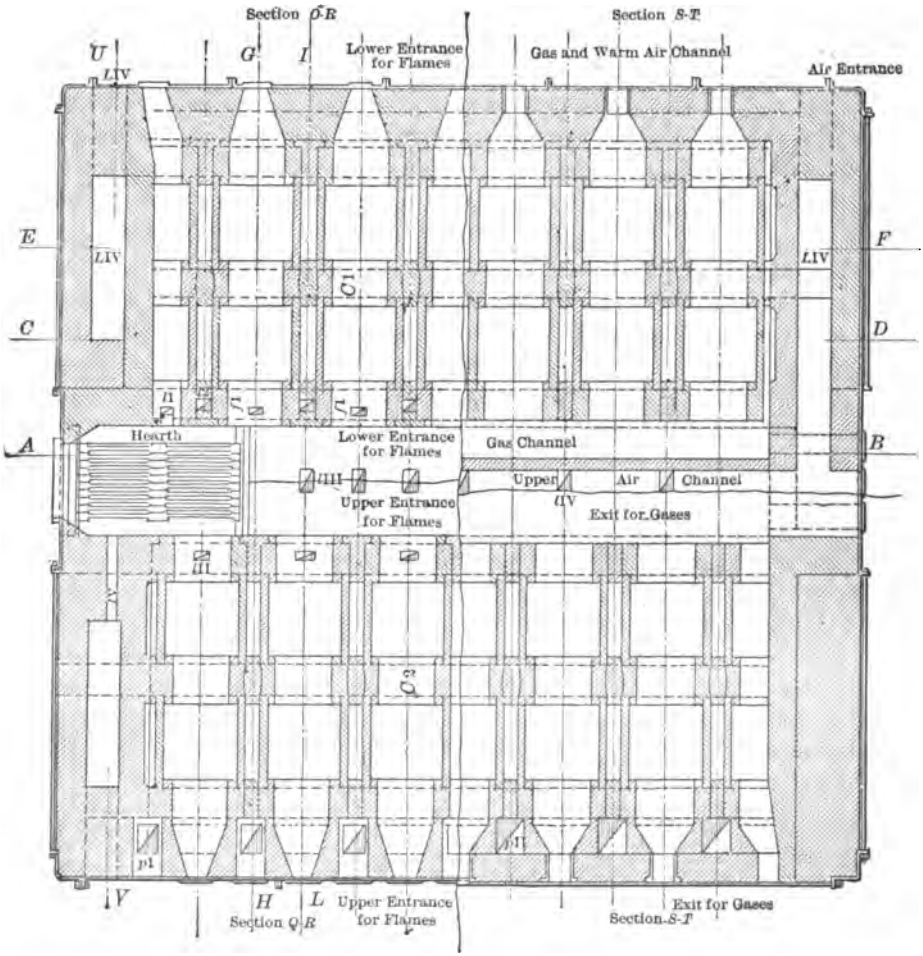


Fig. 1.—Horizontal Sections, *O-R*, *Q-R*, *S-T*.

THE CERMAK-SPIREK FURNACE FOR CALCINING AND ROASTING ZINC ORES.

and from this point they are drawn longitudinally through the tile passages back and forth from tier to tier until they reach the outlet at the top of the furnace. For the calcining process a high temperature (1,100°C.) and a thorough roast are necessary, hence the full area of the openings are taken up by the flames. By providing two separate entrances for the flames it is possible to effect a thorough roasting of mixed ores that are to undergo a subsequent magnetic concentration by using the upper flame alone. The required amount

of fine coal can then be introduced by means of long shovels and the material be brought to the lower part of the furnace where after closing the air entrance it is subjected to the reducing action of carbon monoxide by which the ferric oxide formed during the first operation is reduced to magnetic oxide. During

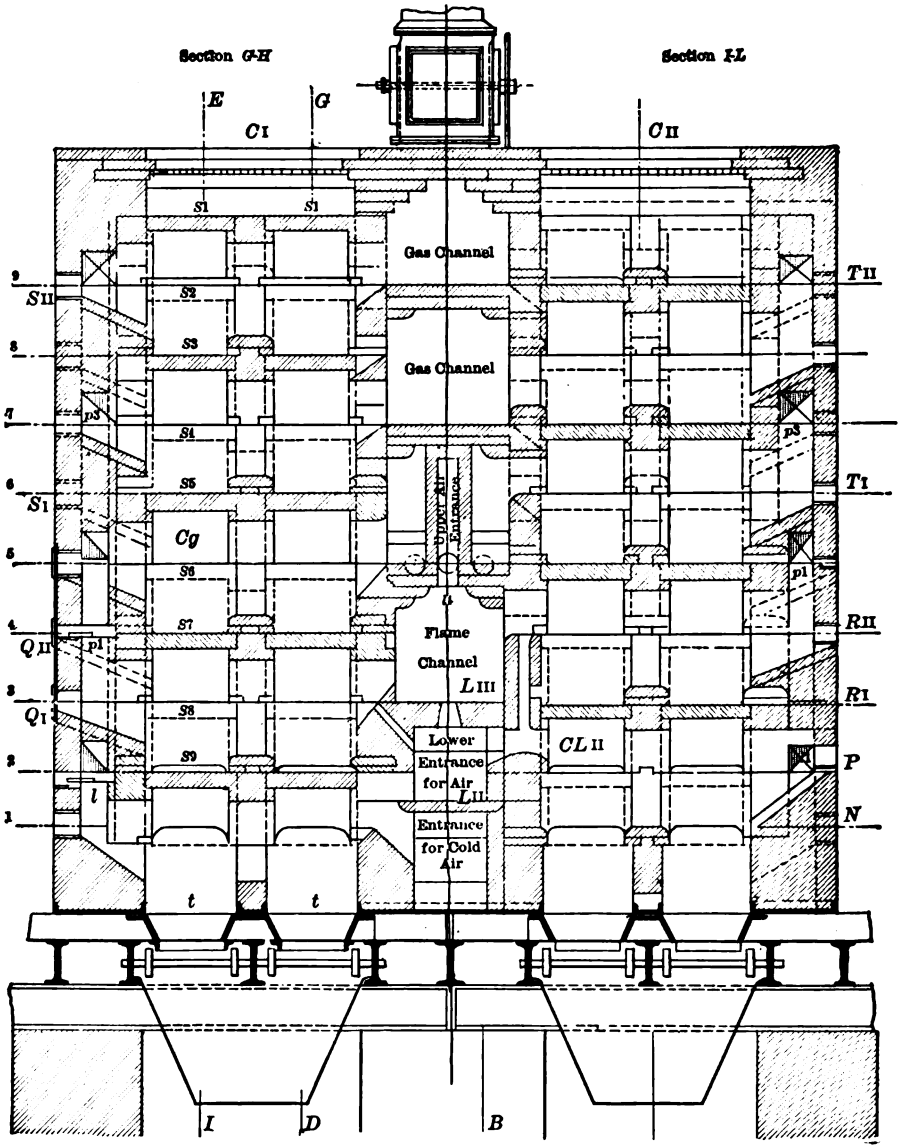


Fig. 2.—Vertical Sections, *G-H*, *I-L*.

THE CERMAK-SPIREK FURNACE FOR CALCINING AND ROASTING ZINC ORES.

the second or reducing stage the upper flame entrance should be closed. The gases pass through the four channels and may be used to heat the descending ore. At Ponte di Nossa this is effected by conducting the gases through horizontal covered channels before entering the chimney. The results of a four-

months' run of this furnace have been published by Ernesto Zay and Arthur T. Francis in the *Resoconti della Associazone Mineraria Sarda,* 1901, Vol. VI. The amount of smithsonite treated was 1,145 tons for which 97·5 tons of coal were required or 8·5% of the ore. The furnace was handled by three men

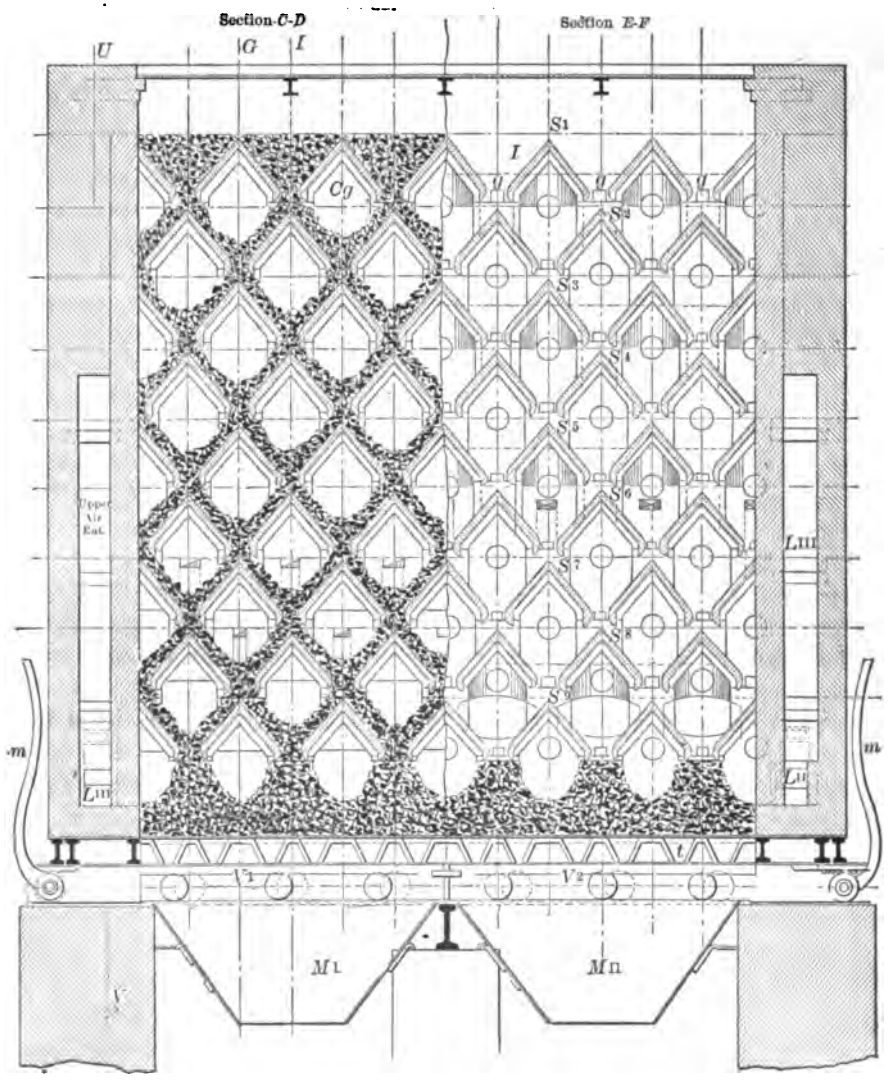


Fig. 3.—Vertical Sections, *C-D, E-F.*

THE CERMAK-SPIREK FURNACE FOR CALCINING AND ROASTING ZINC ORES.

working in 8-hour shifts and two boys. The total costs amounted to 5·51 fr. per ton of ore. During December, 1901, the furnace was used for roasting zinc blende, but the results are not available for publication at this time. Dimensioned illustrations of the original form of this furnace will be found in THE MINERAL INDUSTRY, Vol. VI., p. 572.

Mining and Milling in the Joplin District, Missouri.

By Frank Nicholson.

The depths of shafts in the Joplin district range from 312 ft., the deepest, down to a few feet only; the average depth of the working mines being about 130 ft. The general tendency during the past two years has been toward a greater depth and there are more mines operated below the 150-ft. level to-day than ever before. The mines do not become richer with depth nor is there any appreciable falling off in the values; it is quite noticeable, however, that at increased depth, the iron pyrite gives out and the resulting zinc concentrates are of higher grade than those produced from the upper levels of the same property. At the present time the total number of shafts in the district, including those abandoned, runs well up into the thousands. Of these there are probably 750 being operated.

Mining.

There has been a definite decrease in the cost of mining ore since the year 1899, and while the cost of supplies and labor is practically unchanged, there has been a steady improvement in methods and more attention has been given to economic handling. The general character of the work also has improved; the timbering is more substantial and more accurately placed with reference to the stress to be withstood, faces are usually carried larger where due regard to safety will permit and the general administrative talent is more efficient. It is rare at the present time to see a property where the total charge for mining and milling exceeds $1 per ton of mine-dirt, yet it was not infrequent three years ago to find the working charges as high as $2 and even $3 per ton of mine-dirt handled.

The total production of the district for the past three years is given in the subjoined table as follows:—

Year.	Zinc Ore.	Lead Ore.
	Lb.	Lb.
1899.....	511,657,470	48,212,720
1900.....	484,660,410	59,013,390
1901.....	516,612,270	70,590,450

These figures show that while the production of zinc ore for the year 1901 was slightly in excess of 1899 and considerably in excess of 1900, the increase was practically unimportant and not at all in accordance with what naturally might have been expected. While a number of new properties are being developed from time to time, others are being exhausted and abandoned. Some of the best producers in the list of 1899 are now making no "turn-ins"; and in other cases the production has fallen off to insignificant figures. These results are partially accounted for by the fact that the year 1899 was one of phenomenally high prices, averaging for the whole year above $40, while since then the average price has been about $25 a ton. Prospecting in 1899 was stimulated and many properties were worked at an actual loss, even with the high prices then ruling. At the

present time the industry is on a safer and more substantial basis and it seems reasonable to look for a steady improvement in the future. No sensational increase in production however can be expected until there is another meteoric rise in price which will permit the profitable operation of lower grade ore bodies.

An important change in the methods of mining has been the increased use of machine drills. In 1899 few mines outside of the blanket-vein district of Prosperity used air drills; while at present they are used in most of the hard ground properties, and on one 80-acre tract near Carterville 20 machines are in operation.

The drainage of the mines has become less and less burdensome as the underground reservoirs have become gradually emptied. In fact, as will be mentioned later in this article, there is good reason to believe that within the next five or ten years the mines will not furnish sufficient water for use in the concentration of the ore; in some respects, however, this condition has its advantages, as it will enable the miners to operate the deeper levels. In the early days of Joplin, the Cornish pump, locally known as the "walking beam," was practically the only one to be seen. It cost little to erect a pumping plant of this type, its maintenance was less than that of any other type, and but little technical skill was required. Later the steam pump was introduced and for all emergency purposes it is without doubt superior to the Cornish pump. Still later, when the mines were opened up and the average flow of water ascertained, it was found that no other pump could compete with one of the Cornish type in the cost of maintenance and regularity of action. Its superiority is not only shown in the developed mine, however, but even in sinking, unless the flow of water should fluctuate excessively. Even in this case the Cornish pump for ordinary work, with a good sinking pump in reserve, is to be preferred to the steam pump alone.

With regard to the geology of the Joplin district, but few papers of real merit have appeared among the many written. A continued study of the district and an examination of a large number of surveys of the underground workings confirm me in my belief, as expressed in 1899, that these deposits are all of the cavern type. They are more or less irregular and approximate in shape the limestone caverns of other districts; the only difference being that they have been filled with zinc and lead sulphides which have cemented together the fragmental masses of flint which have fallen into the caverns after the limestone had been dissolved and removed by water carrying carbonic acid. It seems reasonable to believe that all the ore was originally deposited as sulphide, though evidence is at hand not only of the oxidation of the sulphide to carbonate and silicate, but of the reverse of this process on a small scale; that is, the solution of the oxidized forms as sulphate and their redeposition as sulphide by means of the hydrogen sulphide resulting from the decay of organic matter. It not infrequently happens that pick handles are found in the old workings encrusted with small crystals of zinc sulphide (jack). This is pointed to triumphantly by the tyros as evidence that all the ore in this district was derived originally from the oxidized forms, while as a matter of fact it does not prove it, but simply indicates that the process is possible.

MILLING.

The year 1899 was the culmination of one of the periodic booms that have visited the Joplin district from time to time. Ore prices soared from $28·40 a ton in January to $55 a ton in April. The result of this fluctuation in price was that the more enthusiastic and visionary among the operators and promoters threw discretion to the winds and even the most conservative found it difficult to retain their equipoise in the midst of the rush for properties and the astounding prices paid for lands that had hitherto lacked tenants at any price. New 10-year leases were executed and sold at surprising figures for cash. The natural result of this state of things was that many mills were erected on leases that did not justify the expenditure, and, as a consequence, the traffic in second-hand mills during the past two years has been vigorous.

A careful enumeration of the mills in June, 1901, showed 527 concentrating plants with an average capacity of 100 tons each per 10-hour shift. Of these mills, 300 were running with more or less regularity; while the others were idle, the ground on which they were located being barren of workable bodies of zinc ore or unable to pay expenses at the existing low price for ore. A large number of second-hand mills came into the market and the ruling price for a standard 100-ton mill dropped to $2,000. Many mills of inferior construction were sold at even lower prices, some selling as low as $750. A very large number of mills have been moved from non-paying properties to others of more promise, and at the present time it is unusual in this district to erect an entirely new mill. Second-hand plants are torn down, moved and re-erected at a cost of from $1,000 to $2,500 each, depending upon the size of the mill, length of haul and the weight and character of the machinery. Under this condition the total cost of a new mill is about $5,000, while if ordered direct from the foundry, the contract price would be not less than from $7,000 to $8,000.

Few innovations have been attempted in mill building during the last three years. The most interesting of these is the large brick mill and central power plant erected on the Missouri Zinc Fields' property by the Franklin Engineering Co., of New York. The power plant is equipped with the engines of the Corliss type and generators built by the General Electric Co. The mill machinery is furnished by the E. P. Allis Co., of Milwaukee. The jigs are located on the second floor of the building, and the jig cells vary from the ordinary Joplin type in being shorter in the direction of the flow of the tailings and of excessive width. This mill had to be entirely revamped and was made practically of the Joplin type before it would do the work satisfactorily. After being altered it was able to treat 70 tons of mine-dirt a shift. The mill cost approximately $46,000, while the best Joplin mill can be erected for about $8,000. The Joplin type will treat 125 tons of mine-dirt per 10-hour shift and makes a fairly clean tailings. At present the mill has been idle for more than a year, and it will probably never be operated by the company. The Franklin Engineering Co. also designed the Devonshire mill which recently burned. This mill cost about $12,000 and like the Missouri Zinc Fields' mill it had to be changed to the ordinary type before it would successfully handle the ores of this district.

As emphasized in a previous paper, the treatment of Joplin ores has been evolved by long and patient effort. Almost every conceivable device has been tried and the good features of each retained, while those devices proving unsatisfactory have been discarded. It has been a natural evolution and the present standard mill, while leaving from 1 to 1·5% and even higher values in the tailings, is distinctly superior to any other type of concentrating plant for the special work to be done.

During 1901 a new type of jig, known as the "New Century Quick Drop Jig," has been invented and tested very successfully at Joplin, producing high grade concentrates and clean tailings on almost every sample treated. The plunger of the ordinary jig is actuated by an eccentric which gives it a uniform motion from one end of the stroke to the other, while the new jig is actuated by a spiral cam giving a uniform motion to the upward movement of the plunger and a sudden quick movement to the downward stroke (see Figs. 1 and 2). The results obtained in exhibition tests with this jig have been surprisingly good. There is no mill in the district, as far as is known to me, that is equipped with these jigs, the Cooley type being generally employed.

Further progress has been made in the separation of iron pyrite from zinc blende, and two plants are working along the same general lines, although using different devices. Both give the concentrates to be treated a short, hot roast which changes the pyrite to ferric oxide and affects the zinc ore but slightly. The roasted concentrates are cooled and passed over an electric separating machine which takes out the iron oxide. One plant is in operation near Joplin and the other at Webb City. Both accomplish a clean separation at a cost of about $2 per ton of concentrates treated.

There has been a general increase in the steam plants erected during the past year. Three years ago it was rather unusual to find mills with more than one boiler, and at the present time nearly all of the newer mills are equipped with two 80-H.P. boilers, which enables them to run more continuously than heretofore.

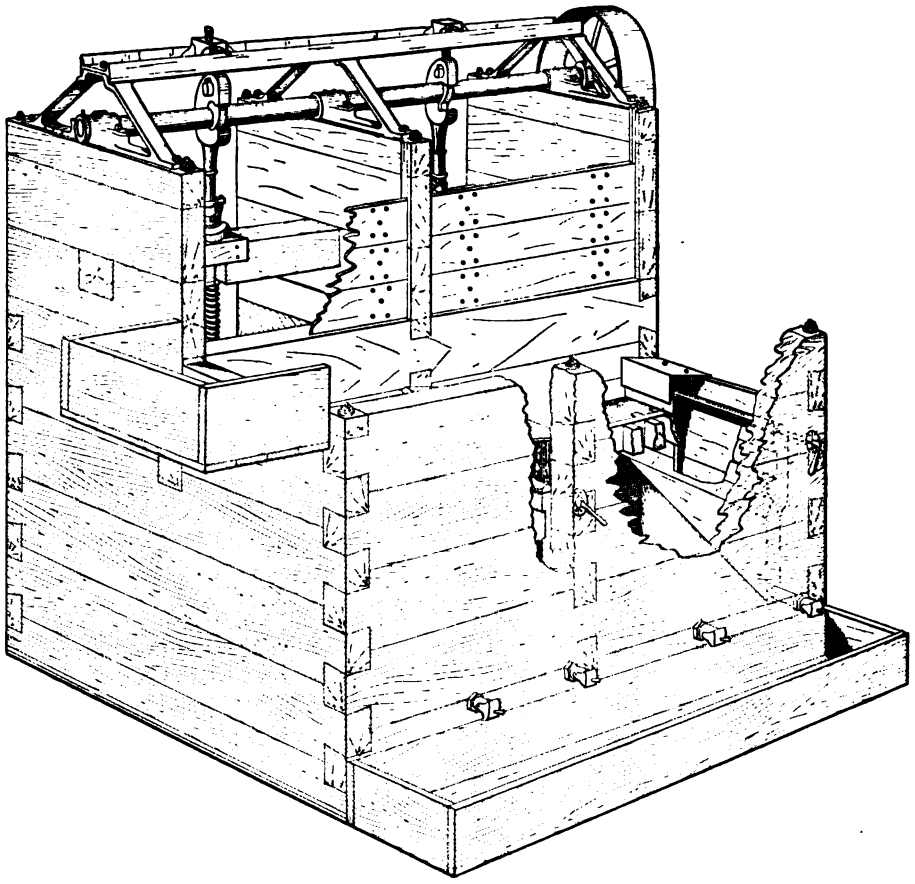
Another variation in practice which has resulted from the extra grate surface is that many mills burn either mill-run coal or slack, while formerly mine-run coal was almost invariably burned. The Joplin district is especially favored in the matter of fuel, as the eastern tier of counties in Kansas, adjoining this district, produces a large amount of coal which is sold at the pit's mouth at prices ranging from 50c. per ton for slack to $1·50 for mine-run.

The average freight rate throughout the district is 60c. a ton. The average fuel consumption is 2·5 tons per shift per mill of mine-run coal and about 3·5 tons of slack. The fuel cost per shift therefore ranges from $3·85 for slack to $5·25 for mine-run. In some cases a small amount of cord wood is burned in connection with the slack.

In former years the ground being but partially drained, large quantities of water were available in almost every section where milling operations were carried on. As the mining progressed and the number of pumps multiplied the ground became gradually drained and now one of the most serious questions to be met is that of securing sufficient water for washing purposes. On the average

to treat the mine-dirt of this district under the system now in vogue ten times the weight of water is required.

Nearly all of the mills have settling ponds and use the water repeatedly, the only loss being that resulting from seepage, evaporation and moisture remaining in the tailings, which averages in all 20% of the total amount used; in other words, a 100-ton mill requires an additional 200 tons of water added to its supply



Portions cut away to illustrate the details of construction.

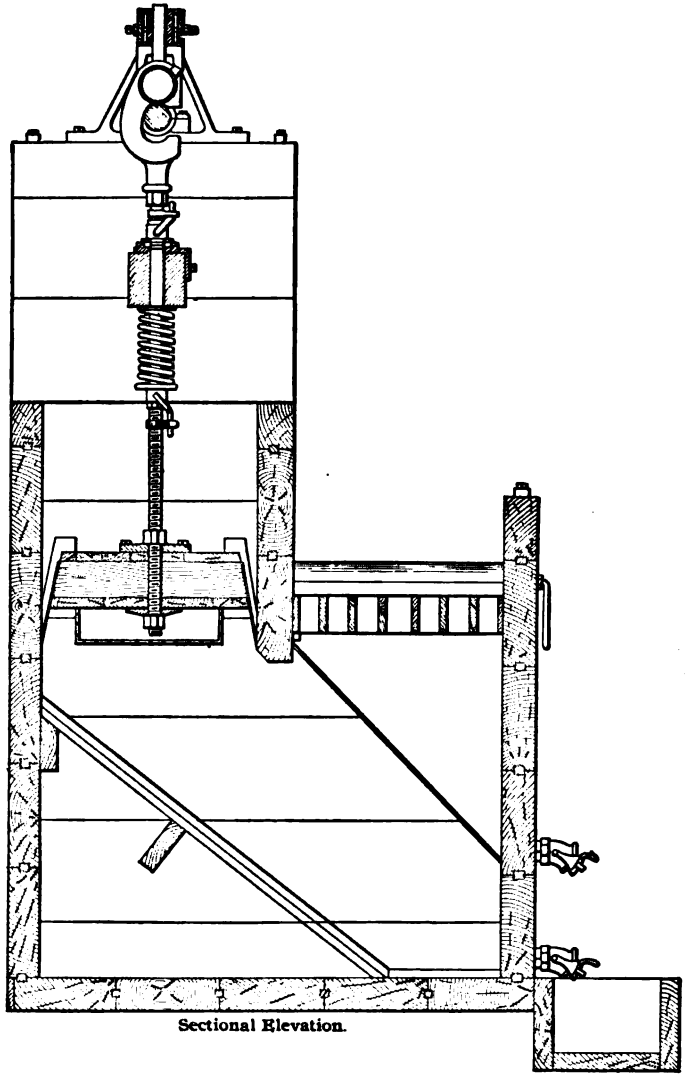
FIG. 1.—THE NEW CENTURY JIG.

ponds each day. In many cases water is being purchased by the plants at the rate of from 8 to 10c. per 1,000 gal., and the City water works and a number of private firms do a lucrative business in this field. It is the opinion of many operators that within the next five years the water question will have become vital, and most of the plants will have to purchase their water supply. It is the invariable rule in every section of this district that as mining proceeds the underground reservoirs are gradually drained and the pumping difficulties diminished.

From time to time a number of mills have been built in the Joplin district.

with capacities ranging from 200 to 300 tons. These, however, have in all cases been less successful than the standard 100-ton mill.

Manganese steel roll-shells have been tried in this district with excellent results; but are not however used extensively for the reason that on ordinary ores they tend



Cross section illustrating the drop-motion plunger's mechanism and ore bed draw-off.

FIG. 2.—THE NEW CENTURY JIG.

to wear as smooth as glass. One set of these shells at Aurora have worn more than a year and are still in good condition, having crushed approximately 30,000 tons of mine-rock. The most popular shell and the one in general use is of chilled iron made by a local foundry. These shells wear on the average about three

months, and as they cost about one-fifth as much per pound as the manganese steel sheels, they are generally preferred by the operators.

In a district like Joplin there is naturally a large number of mine superintendents, who, as a rule, are not engineers, nor even men of the highest grade of intelligence. Most of these men have come from the East, where they have hitherto followed some other calling not in any way identified with mining, and when they reach Joplin they have everything to learn. Fortunately, there is a supply of thoroughly competent ground men to be had in this district, who have worked in the mines all their lives and have frequently operated leases on their own account and are endowed with a skill and shrewdness which render them very valuable as mine and mill foremen. The native Missourian is a good worker and a shrewd bargainer, frequently over-shrewd, and it not infrequently happens that a superintendent without any experience whatever is enabled to operate a mine successfully with the help of one of these capable natives. However, in this as in all other departments of industrial effort, technical knowledge and skill are coming to be more and more appreciated. The mine superintendent of the future will be a technical graduate and this will have its beneficial effect in the future development of the district.

PROGRESS IN PYRITIC SMELTING DURING 1901.

By Franklin R. Carpenter.

The most important application of pyritic smelting during 1901 has been made by Herbert Lang to the smelting of arsenopyrite ores of the Blue Dick mine, at Prescott, Ariz. These ores consist essentially of a mixture of quartz and mispickel, associated with small quantities of iron pyrite, galena, chalcopyrite, tetrahedrite, barite, and spathic iron. The ores are sorted so as to contain about 45% SiO_2, and 17% each of Fe, As, and S, the balance being Pb, Cu, CO_2, etc., and to the mixture is added about one-half its weight in limestone. The slags were made very siliceous to insure the complete decomposition of the arsenopyrite and the volatilization of the arsenic, thereby avoiding the formation of speiss, which would otherwise occur. The smelting was done in a small furnace of peculiar construction, covered by patents which, however, is not essential to the process. Equally good results could doubtless have been obtained in an ordinary furnace. The slag was of the following composition: SiO_2, 40 to 45%; FeO, 24 to 27%; CaO, 20 to 24%, S, etc., to balance. Nearly 90% of the iron was oxidized and slagged, 94% of the sulphur was carried off with the furnace gases or passed into the slag, and the whole of the arsenic was volatilized. The furnace was 3 ft. in diameter, and treated more than 50 tons of ore per day, using a light and cold blast. Mr. Lang is of the opinion that under proper conditions with a hot blast the capacity could be increased to 100 tons or more per day.

A plant has been erected at Rapid City, S. D., under the supervision of Theodor Knutzen, to smelt the siliceous ores of that section, which are similar to those smelted first at the Deadwood & Delaware plant, at Deadwood, S. D., and later by the Golden Reward Co., as described in The Mineral Industry, Vol. IX. The Rapid City plan differs from the one at Deadwood, as it will use a heated blast, and limestone for flux instead of dolomite.

B. F. Morley has rebuilt the old Buena Vista plant, at Buena Vista, Colo., and is very successful in treating the siliceous gold ores of the Mary Murphy mine. The furnace is 34×120 in. in section at the tuyeres, and the blast is produced by a large Green blower. The ores average SiO_2 55%, CaO 4%, Cu 0·1 to 0·5%, Fe 4%, MnO 3%, Al_2O_3 5%, Zn 8%, Pb 1 to 3%, S 8%, and are smelted with iron pyrite from the Leadville district, carrying an excess of about 38% Fe, and from 0·2 to 0·5% Cu. To the charge is added limestone, so the resulting

slag consists of SiO_2 41%, Fe 18%, CaO 18%, with Al_2O_3, Zn, MnO, etc., to balance.

At Keswick, Cal., the pyritic process has been used to smelt the heavy chalcopyrite ores of that section, and while very promising, it has not yet been wholly successful. The first plant for the treatment of these ores by the pyritic process was built a few years ago by Herbert Lang, with the intention to smelt the ores raw, using a blast heated by the molten slag. Later the ordinary German process of roasting and subsequent matting was used, which offered no difficulties metallurgically, but proved unsuccessful financially. There was a change of superintendents, and a return was had to raw smelting, this time heating the blast by the ordinary U-pipe stove. During the prevalence of high prices for copper, the raw smelting process at Keswick was claimed to have been successful, both financially and metallurgically, and the grade of matte made was as high as that produced by previously heap-roasting the ores. Seven large furnaces, each with its own hot-air stove, were erected but for some reason a return was recently made to a preliminary heap-roasting of at least a part of the ore charge, showing that while raw smelting may be theoretically correct, the mechanical difficulties of the process are often well nigh insurmountable. Through the courtesy of D. H. Conolly the following notes have been communicated of a run of 168 hours upon the No. 4 furnace at Keskick, Cal.:—

DAILY RECORD OF 168-HOUR RUN AT NO. 4 FURNACE, AT KESWICK, CAL., DECEMBER 21 TO 28, 1901.

Day of Month.	Crude Ore.	Raw Matte.	Porphyry.	Limestone.	Slag.	Coke.	Copper Contents of Matte Produced.	
							Day.	Night.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	%	%
21	141·0	.....	31·4	14·1	33·4	4·23	.....	18·6
22	207·0	.....	45·1	20·7	51·7	4·71	18·0	19·0
23	183·0	10·0	39·5	17·3	58·2	6·46	19·5	15·4
24	200·0	.....	40·0	13·2	63·6	4·00	16·3	20·6
25	180·5	18·3	35·9	8·9	66·0	4·30	16·8	19·3
26	182·0	25·4	45·0	8·7	72·9	5·88	20·2	22·3
27	145·5	18·6	37·6	7·5	56·1	4·17	19·8	21·3
28	37·5	5·1	8·7	1·1	14·8	1·35	20·4	.....
	1,276·5	77·4	283·2	91·5	416·7	35·00	Average. 18·7	19·5

Total burden.. ..... 2,146 tons. Coke used..... 35 tons.

The blast was heated to 600° F., and the total cost (for furnace work and fuel—excluding office expenses, power, and cost of flux) was, for the entire run $1,487·50, detailed as follows:—

35 tons coke	$13·00	$455·00
75 cords wood for heating blast	3·50	262·50
Labor, seven days	110·00	770·00
		$1,487·50

These costs per ton of burden are:—

Coke	$0·21
Heating blast	0·12
Labor	0·36
	$0·69

The amount of coke used was 1·5% of the total burden, or 2·5% of ore and matte charged.

In analyzing the above report it must be remembered that the ores are mixtures

of massive pyrite, and chalcopyrite, yielding a low content of copper, and that silica in the form of "porphyry" is added to slag the iron in the charge, a case which is the reverse of that at Buena Vista, where pyrite is added to the charge.

At Golden, Colo., I recently erected a plant for the treatment of the siliceous ores of Gilpin County, and as these ores are the typical iron sulphide of ordinary fissure veins, a full description may not be out of place. The ores consist of the altered granitic country rock, and iron pyrite, carrying small amounts of copper, gold and silver. At the mine they average 50% SiO_2 and 6% Al_2O_3; the remainder being considered as essentially iron sulphide. These ores resemble those at Butte, Mont., except that the principal value is gold instead of copper. The usual treatment of ores of this character is to mill and amalgamate them for the gold, and subsequently concentrate the sulphurets, which are sold to the smelters. More recently amalgamation has been omitted at many mills, the ore being concentrated by jigs, or upon tables, and the resulting concentrates sold,—a treatment which is similar in all respects to that used at Butte upon copper ores. Owing to the losses inherent in water concentration, I proposed to smelt these ores direct as they came from the mine.

The recently completed plant is equipped with boilers, engines, pumps, dynamos, ore bins, etc. The furnace is 3×16 ft. in section at the tuyeres, and has a 13-in. bosh in 5 ft. height, above which the walls extend vertically to the top of the shaft. The distance from the furnace floor to the feed floor is 22·5 ft. There are 16 tuyeres upon each side of the furnace, bushed down to 3-in. openings. A No. 8 Connersville blower is used, which displaces 100 cu. ft. of air at each revolution, and is usually driven at 125 revolutions per minute. The stove is of the ordinary U-pipe style, consisting of 60 pipes, each 12·5 ft. in length, and 8 in. in diameter. Twelve tons of cheap lignite coal are consumed in 24 hours, and 12,500 cu. ft. of air is heated to a temperature of about 700°F.

The charge consists of 1,000 parts of siliceous pyrite, 600 parts of limestone, 200 parts of clean pyrite, and 180 parts of coke of very poor quality. Under favorable conditions, 300 tons of this charge are smelted in 24 hours. Limestone has been almost excluded at times, and the quantity of coke much diminished, pyrite being substituted for it, but the results were not satisfactory. The furnace is tapped from the end, and is probably the longest furnace in the world so tapped. The molten contents flow into a cast-iron forehearth, 4×6×2·5 ft. deep placed on wheels, and the best results are obtained when the silica in the slag is kept between 40 and 45%, which is maintained by increasing or diminishing the quantity of clean pyrite used, to conform with the increase or decrease of silica in the ore. The matte is very low in copper, seldom exceeding 8%, and sometimes falling as low as 2%, yet the slags are exceptionally clean, and it is well to note that this result is, apparently, not dependent upon the percentage of copper present. The plant has now been running a sufficient time to know that it can more than compete with the older processes heretofore employed upon these ores.

There is much misunderstanding current regarding the pyritic process, which is kept up especially by those who have "patented" schemes for disposal. It cannot be too strongly urged that, while some of the patented devices may be of value,

there are no essential patents to deter any one from using the pyritic process. It is also well to remember that, while there have been brilliant successes, the greater number of pyritic plants have failed. Those which formerly existed at Boulder and Toston, Mont., and at Leadville, Kokomo, and Ward, Colo., have all, from one cause or other, ceased to run. The large plant at Florence, Colo., has not come up to expectations.

The cases in which the process is most successful are those that approximate the pyritic smelting as described by Dr. John Percy, in which pyrite is added simply as a carrier or collector for precious metals. When pyrite is added for any other purpose, *i.e.*, for a fuel or a flux, it is liable to melt and run away from the charge, leaving the siliceous contents unfluxed, which results in a frozen furnace. This was probably the difficulty at Keswick, Leadville, and other places where the smelting of pyrite ores with little or no carbonaceous fuel has been attempted. The necessary amount of heat-producing constituents is undoubtedly present, if it would only burn, but pyrite is treacherous, and is liable to run away at the first application of heat. At Prescott, Ariz., and at Golden, Colo., the pyrite is so intermixed with quartz that it is held until it is oxidized. I have smelted many thousand tons of Butte copper ores at the Deadwood plant, and have no hesitancy in stating that the whole of the concentrating and roasting machinery employed around the Montana smelting works is unnecessary, provided the process of pyritic smelting is employed that was first developed at Deadwood, S. D. While the ideas there used were in the main derived from European practice, the process was so far modified as to deserve to be known as a distinctively American method of smelting. Many previous attempts had been made to smelt in large blast furnaces a charge consisting of silica, limestone and pyrite, but without success until it was accomplished at Deadwood. At Golden, Colo., the Deadwood practice was materially improved by the addition of hot air, without which pyritic smelting should not be attempted. The process now appears extremely simple, but it has required many years of anxious work and costly experiment to make it so.

THE PROGRESS OF METALLOGRAPHY IN 1901.

By Albert Sauveur.

The introduction of metallographic methods into industrial works in the United States is to be traced to the year 1891, when a metallographic laboratory was installed at the South Chicago Works of the Illinois Steel Co. Since then the interest taken in the subject has grown steadily until at present there are few steel producers which do not submit their products to microscopic examination. Educational institutions also have given due recognition both to the scientific interest and to the industrial value of metallography, and the subject is now taught in nearly all of our important technical or scientific schools.

Large consumers of metals have not as yet come to realize the value of the microscope as a testing implement that will help them in ascertaining the quality of the metals they receive from the producers, and especially in securing better, safer, and more uniform materials. That this appreciation must come is, however, certain.

It is also disappointing to note the indifference of manufacturers of cast iron castings toward metallographic methods. The usefulness of these methods in connection with foundry work is very great; indeed it opens up a field fully as promising as in steel making and steel working.

This growing interest in metallography, just alluded to, continued unabated during the past year. Many new recruits have been made, and the results of some excellent experiments have been published. The interest taken in the subject by manufacturers of alloys calls for special notice. It should not, however, cause surprise, for I believe that in no other field will metallography prove of more valuable assistance than in the production of alloys. To those who are familiar with the little that has been accomplished, it must be evident that the value of metallography could here be hardly overestimated.

In the following pages are presented the most important developments of the past year.

Apparatus.—The requirements of the metal microscopist, who deals with opaque objects, are so different from those of the ordinary microscopist, that the microscopical appliances on the market were not well suited to his purpose. Special stands and special accessories had to be devised in order to meet his needs.

In the accompanying illustration (Fig. 1) will be seen one of these special outfits, including all the best devices that have been thought of to facilitate the manipulations and to increase their efficiency.

On the light table will be seen a special microscope stand, eye pieces, objectives and other accessories, as well as a camera and a Welsbach lamp and condenser. A wide range of work may be covered with this simple outfit, the Welsbach lamp and condenser yielding a very satisfactory illumination for low and medium high powers. In many instances it is all that is needed. On the dark table will be seen a similar microscopical outfit together with an illuminating outfit consisting of an arc lamp and a complete optical bench. The optical bench includes two large condensing lenses, one water chamber, and one large diaphragm. The microscope is placed on the base of a vertical photo-micro camera. On the right is a rheostat through which the current is made to pass before entering the lamp. This illuminating outfit yields an ideal illumination, of great intensity and steadiness, unobtainable by any other combination. It is the only arrangement by which it is possible to throw the image of the specimen directly upon a screen. The structure of the samples may in this way be examined by any number of observers simultaneously, discussed at leisure and with greater profit. The direct projection affords also an excellent means of drawing the structure, greatly superior to the use of the camera lucida. The image seen on the screen represents the structure of medium hard steel as it appears when projected upon it. The original magnification was 500 diameters.

With the assistance of a special polishing machine, it does not require, in the majority of cases, over 15 minutes to polish and otherwise prepare a sample of metal for microscopical examination. The image of the structure may then be thrown upon a screen or photographed if desired. The exposure required with the electric illuminating outfit varies from one to five seconds. By using Carbutt's process plates and drying with alcohol, the negative may be ready for printing within half an hour after the sample has been taken in hand. With a Welsbach lamp the time of exposure is, of course, considerably longer.

Crystalline Structure of Metals.—Prof. J. H. Ewing, of the University of Cambridge, and Mr. Rosenhain have published[1] a very interesting paper on the crystalline structure of metals. From the fact that the structure of hardened steel, *i.e.*, of steel suddenly cooled from a high temperature, is totally different from the structure of the same steel allowed to cool slowly, it is rightly argued that the structure of steel at a high temperature differs greatly from its structure at a lower temperature; that upon slow cooling important change or changes occur in the structure. Again, on reheating a piece of steel past the critical point it is well known that all pre-existing structure is obliterated and replaced by a new crystalline arrangement. It thus appears that spontaneous changes of structure occur in steel, both on heating and cooling. These structural changes, however, have never been observed *while taking place:* the inference that they do occur is based entirely upon the appearance of the cold metal, that is, of the metal *after* the change has been consummated; hence a natural longing to

[1] Philosophical Transactions of the Royal Society, Vol. XIX., p. 279; also, *The Metallographist*, Vol. V., p. 79.

observe these structural transformations while actually taking place. Every metallographist has probably brooded more or less over this problem, and in nearly every instance was probably led to the conception of what appeared the most promising method of solving it, namely, the microscopical examination of a polished and etched steel section while being heated by an electrical current forced through it, and surrounded by a non-oxidizing atmosphere so as to prevent the formation of an oxidized film over the etched surface. The experiment was actually tried by several investigators, but the many mechanical difficulties encountered were not successfully overcome. Messrs. Ewing and Rosenhain were more successful. With great experimental skill they mastered the purely mechanical difficulties, but the results which they report are indeed disappointing. No change of structure could be detected under the microscope while the metal was being heated or cooled under the conditions just alluded to. Upon a very slight re-polishing and re-etching of the sections, however, the structure was found to have undergone the change which was expected. While a structural transformation occurs within the metal, therefore, the pattern of the surface remains unaffected, hiding the change and preventing its observation. The authors very clearly explain this unexpected result in the following words: "The explanation is obvious when we realize that the pattern seen in the microscope is due to the differences of level and texture in the surface of the specimens which have been produced by the action of the acid used in etching. This pattern, although in its origin dependent upon the actual crystalline structure of the metal at the time when the surface was etched, remains as a mere mask, beneath which re-orientation of crystalline elements may go on without affecting its appearance. The etched pattern is in this respect in the same position as a scratch or mechanical marking of the surface, and the persistence of the etched pattern after annealing is simply an extension into more minute detail of the well-known fact that the external shape of a piece of metal is not in general affected by annealing, although the crystalline structure is entirely changed. These considerations show that we cannot expect to see the process of recrystallization in any metal where etching, staining, or relief polishing is needed to differentiate the constituents."

Failing thus to observe structural transformations in iron and steel, the authors turned their attention to the process of recrystallization in more fusible metals, such as lead, tin, zinc, and cadmium. They observed that sheet lead, when properly etched, exhibited large crystals and very frequently twin crystals. A lead surface must be kept wet with an acid solution while it is being examined and photographed, as such a surface becomes dull and useless as soon as it dries. Sheet lead is rolled cold from cast ingots, and yet the crystals of sheet lead exhibit no distortions whatever. We must conclude from this that a recrystallization of the metal took place after the rolling at atmospheric temperature. To throw more light upon this point the authors investigated the changes of structure occurring in cast lead through severe straining, cast blocks of lead being squeezed in a compression testing machine. Fig. 2 shows the structure of cast lead magnified 12 diameters, and Fig. 3 the structure of freshly crushed lead magnified 30 diameters. The specimens of crushed metal were then

examined at intervals during a period of six months to ascertain whether any change of structure was taking place spontaneously at the ordinary temperature. A decided growth of crystals was detected by actual measurement, although such growth is not evident from the appearance of the photographs taken by the authors respectively after six days, one month, four months, and six months. The manner in which the crystals grow is described as follows: "It is seen that the crystals do not grow by the steady accretion of layers all over their surface, but that they throw out arms or branches, which invade neighboring crystals, thus forming a skeleton crystal somewhat similar to those that are often noticed in the crystallization of fused substances."

The authors then subjected samples of sheet lead to a temperature of 200°C. for varying lengths of time, in order to ascertain whether it would result in further crystal growths. "Our observations," the authors say, "show that the metal in this state is very sensitive to moderately high temperatures, three minutes' exposure of ordinary sheet lead to a temperature of 200°C. being sufficient to produce a great change in the crystalline pattern. If the specimens be kept at 200°C. for a long time there is a continued change, but it becomes very slow, and ultimately a state is reached when further change is imperceptible."

Fig. 4 shows the structure of sheet lead magnified 12 diameters; Fig. 5 the structure of the same sample after maintaining it at 200°C. for six days. The triangular markings seen in the photographs are deep scratches made in the polished surface in order to be able to photograph exactly the same spot before and after the annealing treatment.

Freshly crushed lead was then heated to 200°C. and kept at that temperature for a long time. This treatment resulted in a very marked growth of the initially small crystals, some very large ones being detected in various parts of the specimens. The authors' conclusions concerning the recrystallization of lead are as follows:—

(1) "In lead which has been severely strained recrystallization goes on at all temperatures, from that of an ordinary room up to the melting-point.

(2) "The higher the temperature the more rapid are the changes in the crystalline structure.

(3) "The rate of change varies with different specimens, probably depending upon the nature and quantity of impurities present and upon the severity of the strain to which the metal has been subjected.

(4) "The size of the crystals ultimately produced does not vary appreciably between 100°C. and 300°C. In lead annealed at the temperature of the air, very large crystals have not yet been obtained, but this is probably only a question of time.

(5) "The phenomena of growth of crystals occur in lead only when the metal has previously been subjected to severe plastic strains. The structure of a cast specimen remains unaltered at temperatures which cause a strained specimen to show rapid change. By casting in a mold arranged to cause rapid cooling, specimens of lead can be obtained having a minute crystalline structure, whose scale is not very different from that of severely crushed lead; such a specimen was exposed to 200°C. for nearly seven days, but no visible change of

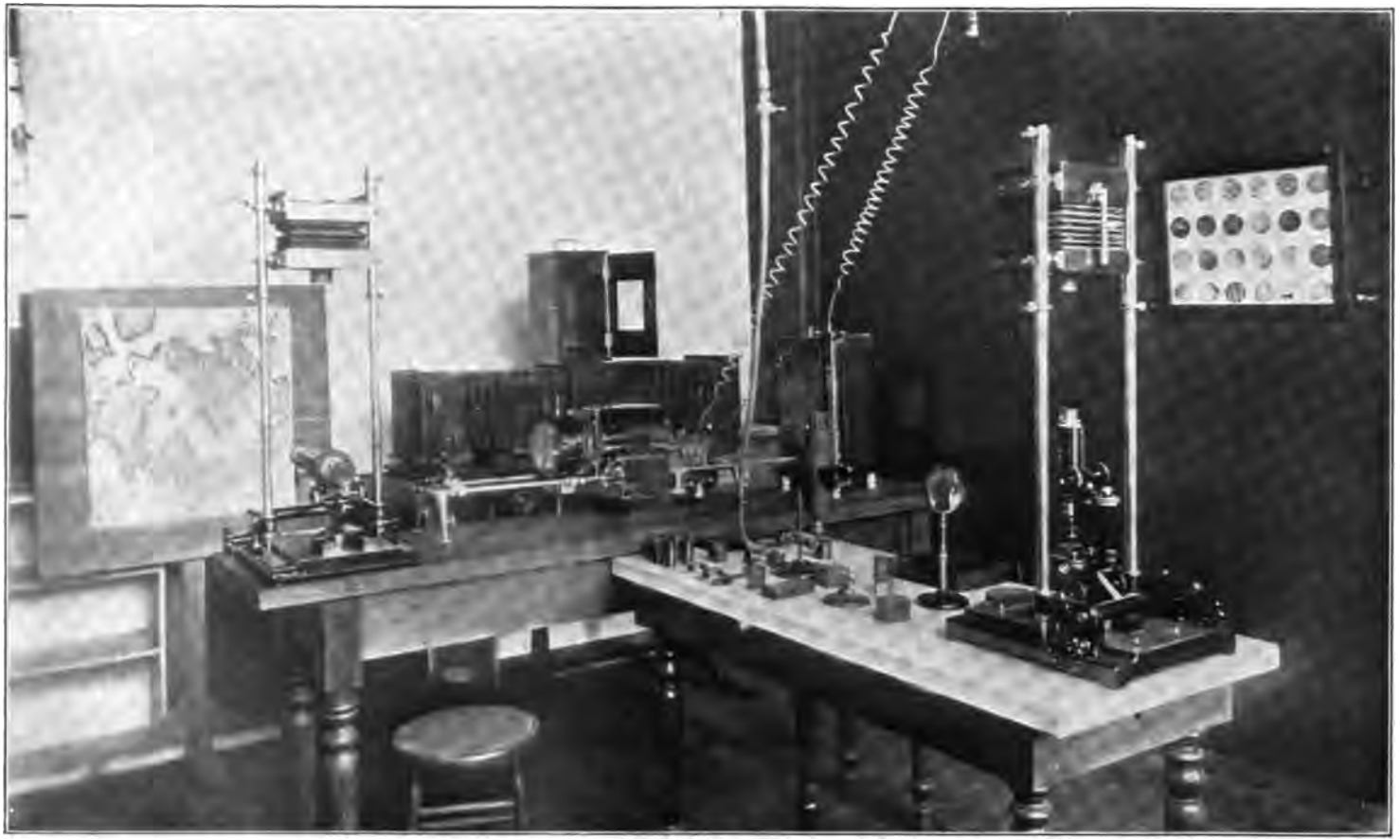


Fig. 1. Laboratory Equipped with a Complete Microscopical Sauveur Outfit for the Examination of Metals and Alloys.

Fig. A.
Sheet Lead.
Magnified
12 diameters.

Fig. 5.
Sheet Lead
(same as Fig. 4)
after Four Days'
Additional Heating
at 200° C.

structure occurred. A piece of this specimen was then strained by severe crushing, and on further exposure to 200°C. vigorous growth took place.

(6) "The rate at which a lead specimen is cooled from temperatures of 200°C. to 300°C. down to ordinary air-temperature has no visible effect on the structure. Even 'quenching' in liquid air has no visible effect; quenching in water, cooling in air, and slow cooling in the oven were all tried on a number of specimens without in any way affecting them.

(7) "Lead is mechanically hardened to a small extent by severe strain, and the subsequent effect of annealing in restoring softness is correspondingly small. In one of the experiments a specimen of lead was crushed under a given load in the testing machine, and the load was left on until no further creeping occurred. The specimen was then annealed and again placed under the same load, when a distinct amount of further crushing was seen to take place."

The authors ascertained next that tin, zinc and cadmium, after being severely strained, recrystallize very much like strained lead. The striking crystalline structure of tin plate is well known, and is illustrated in Fig. 6 (one-half natural size). It will be noted that individual grains are not uniformly dark or bright, but that the brightness shades off across the grain. This appearance is unlike that observed in the crystalline grains of other metals, and we are led to infer from it that in these tin grains the orientation of the small crystals of which such grain is composed is not uniform all through the grain—in other words, that these grains are not true crysttals, since constancy of orientation of the elements is an essential characteristic of a true crystal. The authors, however, are inclined to attribute this feature to "a distortion or bending of true crystalline plates; such distortion would probably arise from differences in the coefficients of expansion of iron and tin brought into action by a suitable rate of cooling. Considering the extreme thinness of the layer of tin, the amount of distortion might well be purely elastic and insufficient to produce slip in the crystals of tin."

Seeing that it is generally supposed that recrystallization in iron and steel occurs at the thermal critical points, the authors endeavored to ascertain the existence of such critical points in lead, tin, zinc and cadmium. Failing to detect any they express their doubt about the relation supposed to exist between the structural changes and the critical points of iron and steel. This doubt hardly seems justified. It has been most conclusively shown that if a piece of high-carbon steel be heated below its critical point, no matter how near to that point, its structure remains unaltered, while if it be heated just above it, its structure is deeply changed. Again, if it be quenched just before reaching the critical point it is not hardened, while if it be quenched just above it, it is fully hardened, and this acquisition of the hardening power implies a radical change of structure. Are these not conclusive evidences of the close relation existing between the critical points and accompanying structural changes? They are both the manifestations of the same transformation. Again the authors overlook here a momentous difference between the recrystallization in lead and tin such as they have observed, and recrystallization in iron and steel. They state repeatedly and emphatically that in the former metals recrystallization takes place only in strained samples, while it is well known that the structure of cast

steel is affected at the critical points as well as that of forged, drawn, or otherwise strained metal. This suggests a difference of origin between the structural changes in steel and those in other metals.

To account for the growth of crystals in metals at low temperatures, the authors proposed an ingenious and most interesting explanation. They argued that even so-called "pure" metals always contain a certain amount of impurities, and that some of them combine with a small amount of the metal itself to form eutectic alloys, that is, alloys which have a lower melting-point than the metal. "It is well known that when a metal containing a small proportion of such impurities crystallizes, the impurities are, for the most part, segregated in the intercrystalline boundaries. The crystals themselves form at a temperature when the eutectic alloys are still quite fluid, and the growing crystals gradually push the remaining eutectic into the boundaries. When the quantities of impurities present is sufficiently great, this eutectic can be seen under the microscope forming an intercrystalline cement. . . . When the quantity of eutectic present is very small, the meshes of intercrystalline cement cease to be visible, but the presence of the impurity makes itself felt by the formation of deep grooves or channels along the intercrystalline boundaries, on etching. Even a very minute amount of impurity would suffice to form a thn but practically continuous film of eutectic in the crystalline boundaries."

The authors contend "that there is constant diffusion upon the surface of the crystal into the eutectic and equally constant re-deposition of metal upon the crystal from the eutectic film. If there are several crystals in contact with the same eutectic, then there will be, under some conditions, a state of dynamic equilibrium between them, the amount dissolved from each being exactly counterbalanced by the amount deposited upon it; if, however, there is any difference in their "colution pressure" in respect to the eutectic, then the less soluble will grow at the expense of the more soluble. . . . The metal constituting the eutectic films being much nearer its melting-point than the rest of the mass, would thus be favorable to comparatively rapid diffusion, but the rate of such diffusion, and consequently, the rate of growth of crystals, would be enormously increased by heating the metal to a temperature above the melting-point of the eutectic in question."

The theory proposed depends upon the existence of a difference in the solubility of the two crystal faces in contact with the eutectic film. The only difference between these two faces is, apparently, in the orientation of the crystalline elements, but this difference ic sufficient, in the authors' opinion, to produce a difference in their rate of solution in the eutectic film, seeing that it results in such marked difference in their solubility in the etching acid, which, as is well known, attacks some grains much more readily and deeply than neighboring ones whose elements have another orientation. To account for the influence of the orientation of the elements upon the solubility of the crystals, the authors suggest to extend to alloys the electrolytic theory of solution. "Such differential actions," they say, "may most probably be attributed to differences of electrical potential in the surfaces involved. If we accept this view of the matter, then the diffusion across films of eutectic becomes a case of electrolysis."

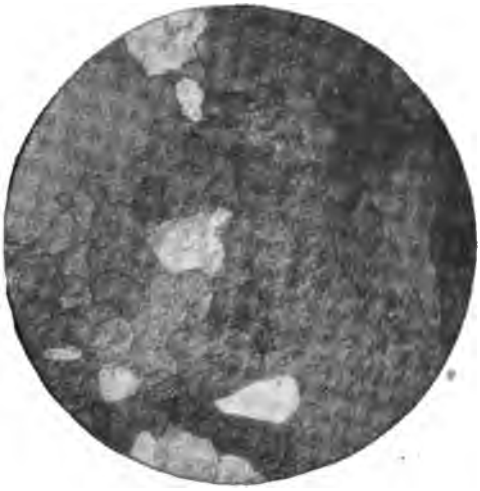


Fig. 2.
Cast Lead, magnified 12 diameters.

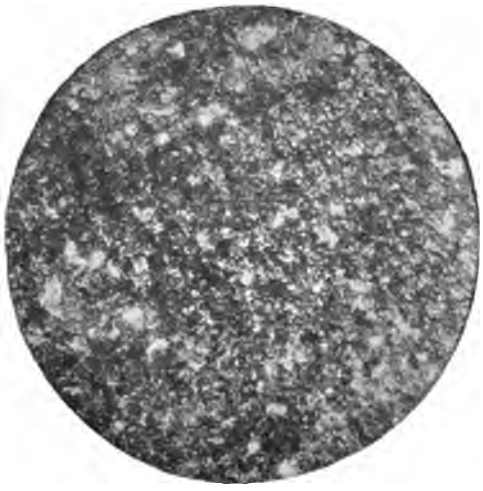


Fig. 3.
Freshly Crushed Lead, magnified 30 diameters.

Fig. 6. Etched Tin Plate, reduced to half size.

Fig. 7. Weld in Lead, magnified 30 diameters.

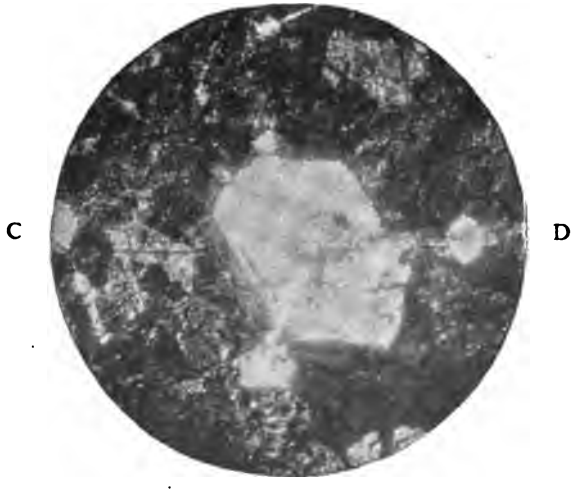


Fig. 8. Weld in Lead, with Eutectic, magnified 30 diameters.

This theory explains why only strained crystals of the metals examined will grow, while unstrained crystals show no tendency to change, even at high temperatures. "The explanation, on the electrolytic theory, is that in the unstrained state the crystals are surrounded by practically continuous films of eutectic, and that electrolysis only becomes possible when severe distortion has broken through these films in places, allowing the actual crystals to come into contact; the electrolytic circuit would then be for each pair of crystals, from one crystal to the other by direct contact and back through the eutectic film."

If the authors' brilliant conception be true, recrystallization by annealing in a perfectly pure metal would not occur, but as they rightly say, it is almost hopeless to obtain a sample of metal sufficiently pure to prove or disprove the theory. They argue, however, that if the growth of crystals is due to the presence of a eutectic film between them, the absence of such film would be a barrier to all such growth, and that a weld between two clean-cut surfaces should show no growth of crystal across the weld. This they actually proved to be the case. Fig. 7 shows the appearance of welded lead after annealing and magnified 30 diameters. The line *A B* shows the weld. It will be noted that the crystals have grown up to the line of the weld and then ended quite abruptly. In no case does a grain cross a weld-line. The weld, therefore, behaved as a true intercrystalline boundary, differing only in the absence of eutectic, and therefore forming a barrier to crystalline growth. The authors then went one step further, and in order to produce a growth of crystals across the weld, in accordance with their theory, they introduced a eutectic film at the weld in the shape of a continuous layer of lead-bismuth, and subjected the sample to annealing to cause the growth of the crystals. No growths, however, took place across the weld, but this they explained on the ground that the eutectic film formed a *continuous* separation between the two lead surfaces, analogous to those forming the boundaries of unstrained crystals, and that a discontinuous eutectic film is required according to the electrolytic theory, to cause a crystal growth. Their next step was accordingly to introduce such a discontinuous film at the weld in the shape of a few small flakes of the same alloy. After annealing the crystalline growth was found to have extended over the weld-line as is well shown in Fig. 8, in which *E D* represents the weld. In the center of the field will be seen a large crystal cut almost in halves by the weld.

The results of these experiments with welded lead point strongly to the accuracy of Messrs. Ewing and Rosenhain's theory. Their work is of a masterly character, both as to experimental skill and intellectual power.

Structure and Finishing Temperatures of Steel Rails.—It is well known that when a piece of steel is allowed to cool undisturbedly from a high temperature, it crystallizes, and that the resulting crystals or grains, as they are frequently called, are the larger, the higher the initial temperature and the slower the cooling. This was first forcibly stated by Prof. Tschernoff in his masterly paper on "The Manufacture of Steel and the Mode of Working It," communicated to the Russian Technical Society in April and May, 1868.

It is also well known that if the steel be vigorously worked (rolled or forged) while it is cooling from a high temperature, crystallization is prevented, but as

soon as work ceases, crystallization sets in until a certain temperature is reached, which in the majority of cases is not far from 700°C., and below which there is no further growth of crystals. If work be performed below that critical temperature the crysttals are permanently distorted, being flattened and elongated in the direction of the rolling and this distortion of the crystals is greater the lower the temperature at which the work is carried on. Such distortion causes a decrease of ductility and, eventually, brittleness, a striking illustration of which is found in the drawing of wire, which must be frequently annealed to remove the brittleness produced by work at a low temperature. The annealing removes the distortion of the crystals and, therefore, the resulting brittleness by causing the metal to assume a new and finer crystallization.

For convenience, the range of temperature during which steel crystallizes, and which extends from the melting point to the critical temperature (about 700°C. in the case of carbon steel) may be called the crystallizing range, and the work performed at these temperatures "hot work," while the work done below these temperatures will be called "cold work." Hot work influences the final structure by preventing or retarding crystallization, while cold work distorts the crystals.

It follows from the above considerations that in working steel, as is done in the manufacture of so many implements, from a high to a much lower temperature, crystallization is retarded, *i.e.*, is made up to cover a much shorter range of temperature, extending from the finishing temperature (the temperature at which work ceases) to the critical temperature. The resulting structure will, therefore, be finer grained, *i.e.*, will be made up of smaller crystals, than if the metal had been allowed to cool undisturbedly from a high temperature; the crystals will be the smaller the lower the finishing temperature. Should work be continued below the critical temperature the crystals will be distorted, which implies a loss of ductility.

It has been conclusively shown that the finer the structure, *i.e.*, the smaller the crystals, the more ductile will be the steel, and since ductility is always a very desirable property, whatever the intended use of the finished implement, the treatment of the metal should be conducted so as to confer upon it the finest possible structure. The importance of finishing steel implements at the proper temperature, therefore, need not be insisted upon. It is now appreciated by all enlightened metallurgists.

The manufacturers of steel rails, more than any other producers of finished steel articles, have given careful attention to the important influence of the finishing temperature upon the structure and the physical properties of their rails. In these days when the tendency is to allow more and more carbon in rail steel, in order to lengthen the life of the rail, the importance of securing all the ductility possible from the heat treatment stands pre-eminently at the front.

The importance of low finishing temperatures was clearly brought out some ten years ago at the South Chicago works of the Illinois Steel Co., as a result of my extensive tests, which were summarized in a paper presented at the Engineering Congress in 1893. In spite of the conclusiveness of these tests however the management could not be made to take up any efficient measure toward lowering the generally too high finishing temperature of the rails. It was assumed that

any step in that direction would interfere with the output and this was not to be considered. While the results given in the paper did not attract much attention at the time, the importance of proper finishing temperatures gradually asserted itself until at the present day there is hardly a steel rail user or producer who is not fully alive to it. The results of many experiments along this line have been published within the last year which confirm the conclusions reached ten years ago.

The Kennedy-Morrison Rail Finishing Process.—The suddenly renewed interest in the subject of proper finishing temperature for steel rails, alluded to above led the Carnegie Steel Co. to a notable departure at its Edgar Thompson plant, from the ordinary mode of procedure. This move on their part was given much publicity and has attracted the attention of all rail consumers. Stated briefly, the modification which they have introduced in the rolling of steel rails consists in holding the rails on a cooling table a few minutes before subjecting them to the last pass. It is argued that by so doing the rail is finished at a lower temperature, which is the desideratum sought.

Looking critically into this new departure in rail rolling, it is observed that the rail, when it reaches the cooling table before the final pass is at a high, or relatively high, temperature and is then allowed to cool until a certain lower temperature is attained. During this undisturbed cooling the metal evidently crystallizes and the rail must necessarily enter the finishing rolls in a crystalline condition, which will be the more pronounced the higher the temperature of the rail when it reached the cooling table and the slower and more prolonged the subsequent undisturbed cooling. It also seems as if the single pass to which the metal is subjected after this crystallizing period cannot be sufficient to break up the crystallization just created. On theoretical grounds, therefore, if a material gain results from this method of procedure, I do not see how it can be accounted for. Let us remember that any undisturbed cooling above the critical temperature constitutes a crystallizing period. By partially cooling the rail before the final pass, the crystallizing range is shortened after the rail has left the finishing rolls, but a crystallizing period is created just before the final pass, which is exactly equal in length to the diminution of the final undisturbed cooling. By so doing the total crystallizing range is not decreased, which alone governs the size of the final crystals; it is merely divided, causing a part of it to be located immediately before the final pass and the balance immediately after, so that a rail treated by this process has passed through a crystallizing period of exactly the same length.

The only beneficial effect therefore that can be claimed for this process is that it breaks up the crystals produced just before the last pass, resulting in a finer structure rail. Assuming that the reduction produced by the last pass is about five per cent. it seems hardly conceivable that so slight an amount of work could be effective in breaking a pre-existing coarse structure.

Similar criticisms of the value of the Kennedy-Morrison process have been published by Mr. S. S. Martin, of the Maryland Steel Co., who contends, apparently on good ground, that any undisturbed cooling introduced in the process of rolling, in order to be effective in producing a finer grained rail, must take place at an early period, because then the considerable reduction, *i.e.*, the great

amount of work to which the rail is subsequently subjected, will break up the crystals formed during that undisturbed cooling. It has also been argued, and rightly, I think, that those mills which do not reheat their blooms produce finer grained rails, for the simple reason that they finish their rails at a lower temperature.

To sum up, in order to confer a fine-grained structure upon steel rails, three courses seem to be opened:—

1. To shorten the crystallizing period, *i.e.*, the time during which the rail is allowed to cool undisturbedly above the critical temperature (say about 700°C.). In other words, the rail should be finished sufficiently cooled, and the finishing temperature will, of course, depend in turn upon the temperature of the ingot when rolling begins and upon the speed of the operations. The main objection to starting and carrying the rolling at a relatively low temperature is that it throws more work upon the rolls. The objection to a slow rolling speed and handling of the material is that it decreases the output of the mill. Both objections imply an increase in the cost of the rail.

2. To cause a part of the crystallizing period to occur previous to the final pass, *i.e.*, to allow the rail to cool undisturbedly at some stage of the operations, and for a short time, before completing the rolling. This cooling in order to be effective should occur at a sufficiently early stage of the rolling, in order that the resulting crystallization may be broken up through a sufficient amount of subsequent work and reduction. Such results would be obtained by placing the cooling table at the shears. The objection to this course is that the shaping of this cooler bloom into rails would require greater mechanical effort and, therefore, increase the cost of production.

3. To finish the rail at the temperature most desirable for easiness and speed of manipulation in rolling and then to reheat it to a temperature slightly above the critical temperature, a treatment which would result in the breaking up of the pre-existing coarse structure, replacing it by a much finer one. This course would undoubtedly be the most effective of the three as it would not only impart a fine structure to the rail, but also a uniform structure to all its parts, while a rail not so treated must necessarily be coarser in the central parts than nearer the cooling surfaces, owing to the higher temperature of the center when the rail leaves the finishing rolls and to its slower subsequent cooling. The cost of such reheating treatment would undoubtedly be very great and, possibly, prohibitive.

The Constitution of Cast Iron.—Prof. Henry M. Howe has published a most important paper[2] on the constitution of cast iron, which takes the discussion on that subject out of the pit and obscurity in which it has raged for so many years to place it in broad daylight on a good sound ground. The attitude and arguments of many foundrymen on the subject of cast iron is a source of incessant wonderment to the metallurgist with a logical and scientific turn of mind. It is gratifying to see Prof. Howe begin his article by stating a truth which foundrymen constantly ignore, namely, that there is no break whatever in their properties or structure, in the series of carbonized iron compounds as we proceed from low-carbon steel to white cast iron. It is absolutely in an arbitrary

[2] *American Institute of Mining Engineers*, February, 1901; also the *Metallographist*, July, 1001.

way that we decide to call cast iron all compounds containing over 2 or 3% C. It is also refreshing to have Prof. Howe state that gray cast iron is steel plus graphite, *i.e.*, is made up of a matrix of steel of varying carbon content through which are disseminated particles of graphite. The contention so often heard that the laws and reasoning based upon the scientific study of steel cannot be applied to cast iron, because it is such a radically different and more complex metal does not for a minute stand the light of searching inquiry.

Since cast iron is merely steel of varying carbon content, with (gray cast iron) or without (white cast iron) particles of graphite breaking its continuity, we should have no difficulty in inferring what should be the structural composition of cast iron possessing certain desirable properties. We only have to remember that as the carbon content of steel (the combined carbon) increases, the tenacity increases up to about 1%, and then decreases, the ductility decreases continuously and the hardness increases continuously; and that the presence of plates of graphite, breaking up the continuity of the mass decreases both its strength and ductility. Looking upon cast iron, therefore, in the light of what it really is, *i.e.*, a high-carbon steel (white cast iron) or a metal possessing a steel matrix through which particles of graphite are disseminated (gray or mottled cast iron), if we desire to obtain (1) a casting of maximum strength: it should be made up of a matrix containing about 1% of combined carbon with as little additional carbon (either combined or graphitic) as possible, since such additional carbon would decrease the strength; (2) a casting of maximum ductility and softness: the matrix should contain as little carbon as possible, and the metal as little graphite as possible; (3) a casting of intermediate properties: the matrix should contain an amount of combined carbon varying between 0 and 1% according to requirements and the metal as little graphitic carbon as possible; (4) a casting of maximum hardness: it should contain as much combined carbon as possible and no graphitic carbon (white cast iron). It is seen that it is never desirable to have over 1% of total carbon present, but since in cupola practice the amount of total carbon absorbed by the iron can only be controlled between very narrow limits (varying generally between 3·5 and 4%), it is only by regulating the relative properties of combined and graphitic carbon that we are able to approach the properties desired. To do so we must regulate properly the amount of impurities, and especially of silicon, sulphur and manganese present in the iron and the rate of cooling (size of castings, chilling, etc.), since these factors all influence the formation of graphitic carbon or the retention of the carbon in the combined condition.

It also follows that in the so-called "air furnace" in which pig iron is melted under oxidizing conditions, a stronger cast iron can be obtained, since it is possible to decrease the amount of total carbon, and this is confirmed by experience.

MINE TIMBERING AND THE SUPPORT OF EARTHWORKS.[1]

By Wilbur Edgerton Sanders.

The term "Earthworks," in its broadest sense, includes many engineering works and the various operations connected with the extraction of materials of economic value from the earth's crust, and it comprehends excavations in solid rock as well as in the looser materials forming a part of the superficial deposits of the earth. Technically speaking, the subject is divided along natural lines into "Engineering Earthworks" and "Mining Earthworks"; the former class dealing especially with construction enterprises, while the latter has for its object the extraction of materials from or from beneath the surface of the earth. While the operations carried on under either of the above branches of the subject are founded upon the same principles yet are their requirements and conditions usually dissimilar, and for this reason the details of the work are often handled in different ways.

Both Engineering Earthworks and Mining Earthworks may be subdivided into three classes: Embankments, or earthworks made by filling; Walls, those made by building and by cutting; and Excavations, those made by cutting. Excavations may be still further classified as of two kinds: Surface Excavations or those open to the sunlight, which include trenches, open-cuts and quarries; and Underground Excavations, comprising those earth-workings that are shut in from the sunlight and which are covered by overlying formation.

All earthworks must in some manner be supported, whether such support is afforded by natural or by artificial means. The natural supports are furnished by the materials of which the works are constructed, as is the case with embankments and walls, or those in or through which the workings are excavated, as when the natural rock enclosing earth-workings is of texture and strength sufficient to resist the pressures bearing upon them. The artificial supports are furnished by extraneous materials applied to resist pressure-forces, in evidence or prospective, and are especially adapted to specific uses.

As regards the science of support, all earthy matter in and through which earthworks are excavated may be divided into two classes that are indicative of

[1] A comprehensive treatise on this subject is now being prepared by Mr. Sanders to be published by The Engineering and Mining Journal (Inc.) in the near future. The work will be eminently practical and fully illustrated by plates taken from working drawings, methods in vogue at metalliferous and at coal mines as well as the support of large tunnels, etc.—Editor of The Mineral Industry.

the normal and abnormal physical characteristics of enclosing and supporting formations; for upon these characteristics, as well as upon the nature and extent of the workings themselves, depend in great measure the employment of natural and artificial methods of support. In this classification it is well to assume as of the normal type those rocks that possess such physical characteristics of strength, hardness and density, cohesion and toughness, as shall enable them of themselves to support to a greater or lesser degree the weight and other pressures bearing upon and tending to destroy the workings. On the other hand the abnormal physical characteristics of earthy matter are those which are due to changes, physical, chemical and dynamic, that affect the texture, solidity or coherence of the rocks and rock-masses, rendering them soft and often even fluid or causing them to separate into parts large or small. Movements of the earth's crust whereby the masses become fractured and broken or crushed, bedding planes, cleavage planes due to pressure and those due to other causes, the circulation of waters that take into solution certain mineral constituents of the rocks and thereby expose them to disintegration, the absorption of water by the feldspars of certain rocks whereby kaolinization takes place and clays are formed, thus causing the swelling ground that presents at once a condition of the greatest difficulty to overcome and one of the greatest dangers to earth-workings; these are but a few of the abnormal features that are developed by excavations in the earthy materials and that must be met and resisted by artificial supports in order that the workings may be kept open and the work prosecuted.

The various kinds of earthworks that must receive natural or artificial support are, as regards surface workings:—

(1) Embankments and Walls; both of which are built up above the surface of the earth, the former usually being constructed of the loose materials of the superficial deposits and depending for support either upon the friction between the different particles of which it is built or upon a retaining-wall of strength sufficient to afford the needed support, the latter constructed of materials of texture and mass possessing strength sufficient to furnish the desired support.

(2) Trenches and Open-cuts.—These workings are very similar in character, the distinction being largely one of relative size. A trench is a narrow cut into the surface of the earth, while an open-cut is a trench of exaggerated dimensions.

(3) Quarries.—Still further differentiating between trenches and open-cuts, as regards the dimensions of the workings, we have the quarry. This class of earthworks may be either of regular or irregular form and though usually of large extent it may nevertheless approach in size to the open-cut. Another distinction lies in the fact that while the quarry is employed for the purpose of "winning" or obtaining materials of economic value at the surface of the earth, and is therefore a branch of mining, trenches and open-cuts have more frequently to do with engineering enterprises.

As regards underground workings the subject of earthworks may be divided into three classes:—

(1) Level Workings.—These are horizontal workings and comprise passageways and stations. Passageways are employed for traffic of various kinds while the stations furnish storage room underground and are also made use of for the

location of mine pumps below the levels that open to the surface. Depending upon the locality, and the uses to which they may be put, level passageways are called adits, adit-tunnels, tunnels, levels, drifts, drives and driveways, tramways, haulageways, gangways, headings, cross-headings and cross-cuts, while stations of the metalliferous mines of the West are known as plats among the coal miners of the East.

(2) Inclined and Vertical Passageways.—These include inclined rectangular shafts, otherwise termed inclines and slopes in the coal regions, and vertical, round, elliptical, polygonal and rectangular shafts, together with those interior mine workings known as raises and winzes.

(3) Extraction Places, oftentimes called Working Places.—These workings are the points at which materials of economic value are attacked and from which they are broken down and extracted. Depending upon the character of the deposit such workings may be horizontal, inclined or vertical. In connection with horizontal and slightly inclined bodies the extraction places are designated rooms, chambers, stalls, and sometimes benches, when the materials are attacked in benches within room, chamber and stall. In the more steeply inclined deposits and when the materials to be excavated occur in large masses, where the surrounding and overlying formation must be supported, such working places are known as "stopes." Depending upon the method of attack, as to whether the material is broken from above or from beneath, these workings may in turn be subdivided into overhand and underhand stopes.

Materials of Support.

The materials that are employed for the purpose of supporting earthworks are: (1) Earthy Materials; (2) Metal; and (3) Timber.

(1) Earthy Materials.—All natural support is afforded by earthy materials, wherein the natural rock in place is made use of to resist the pressure-forces bearing upon and tending to destroy the workings. Here the strength and other normal physical characteristics of the rock furnish the needed support, and in the form of walls, slopes, benches, pillars and pillar-arches are often all-sufficient. More frequently, however, artificial support is necessary, and extraneous materials are employed in specific ways to satisfy the demands of the usual and unusual conditions that are continually developing in earth-workings. Here, too, the earthy materials are employed to furnish support, and rock in various forms is used as also are brick and cement. Rock, cut, broken or crushed into stone of regular or irregular shape and size, and used wet (with mortar or cement) or dry (without such binding material), is built up to form walls, arches, and pillars or bulkheads, while crushed or broken stone is roughly dumped into the excavations for waste-filling or more carefully stowed therein for waste-stowing. Finely crushed or comminuted stone or other earthy material, as tailings and culm, is frequently employed to support underground openings and is filled into them by various methods of procedure. Brick is often employed to furnish support to underground workings and is built up with mortar or cement to form walls, arches, and pillars or bulkheads. Cement, also, is used under certain conditions,

and as walls, arches and pillars supports many kinds of earth-workings. All earthy structures that depend largely or entirely upon the maintenance of their proper form in order to offer their powers of resistance to the pressure-forces bearing upon excavations, and of supporting the workings thereby, can be employed only under conditions that favor the integrity of their construction. Walls, pillars and arches, able to withstand the pressure-forces which they are built to resist, quickly fail when subjected to the grinding action of creeping or moving formations.

(2) Metal.—Iron is the only metal that is employed for supporting earthworks. In the engineering construction of recent years it has largely supplanted the use of timber, stone and brick, as also has it to a considerable degree taken their place in architectural structures. In the use of the metal underground there are restrictions which prevent it from superseding in large measure the earthy and timber supports that are commonly employed in the deep workings. Subterranean waters are frequently charged with chemicals that are injurious and even destructive to iron structures, and for this reason metal is unlikely to replace to any great extent the other materials of support in regions that contain certain minerals and where the solutions that circulate through the earth's crust in those localities are heavily charged with sulphuric acid, copper sulphate or other deleterious constituents. In some places, however, where iron is used for support it possesses a distinct advantage over timber and the earthy materials and, when intelligently employed, its use may frequently be advantageous not alone from an engineering standpoint but from that of economy as well.

As cast iron, wrought iron and as steel, the metal is available for supports. When cast it is used for props to support the roof in the horizontal and slightly inclined extraction places, for posts or legs and the cap or crown of drift and station, gangway and plat sets, for the sole-blocks of gangway sets, and for the tubbing and bearing-rings of vertical round and elliptical shafts. As wrought-iron it is available for supports when rolled into structural shapes, those which are especially adapted to such use being plates, the flat and oval bars, angle beams, channel beams, H and T beams, and rails.

As soft and mild or medium steel it is available for use as supports when rolled into structural shapes, as angle bars, channel beams, I and T beams, and as rails. Both steel and wrought iron in structural shapes are employed as supports in levels and in shafts, going to make up the parts of the regular drift and gangway and plat sets, to form the metal caissons and air-locks for driving level workings and for sinking shafts in running ground and in watery strata, and they are assembled to make up the framework of inclined and vertical rectangular shaft square-sets.

(3) Timber.—For many reasons timber is the most important material from which the artificial supports for Mining Earthworks are constructed; and because of its adaptability to such uses, its applicability in meeting the usual and unusual conditions met with in earth-workings, and the ease with which it may be manipulated, shaped, handled and located, its primary importance as a material for the support of excavations must remain undisputed.

There are two classes of timber in general use for supports: the woods of the

narrow-leaved, naked-seed conifers (pine, fir, spruce, hemlock, tamarack, cedar, redwood, cypress), and those of the broad-leaved trees (oak, ash, locust, chestnut, poplar, cottonwood). Quickly grown hardwoods from rich, warm soils, and slowly grown conifers from high altitudes and the poorer soils, with moderately narrow rings, as a rule yield the most durable woods. The qualities most desirable in timber for supports are strength and elasticity, which characteristics are obtained to a degree in the clear-grained and harder varieties of the conifers. Of two pieces of the same wood the most durable and the stronger is usually the heavier one. Knots and checks within the grain of the wood are sources of weakness, and under end-compression and transverse strain are favorable to sudden breakage without previous warning.

Timber for supporting underground workings should be seasoned where possible before it is placed in position. The main cause of decay in wood is the sap, which sets up a fermentation within the cellular tissues and destroys them; wherefore the trees should be felled when the least amount of fermentable sap is in the wood, usually about December. When the trees are cut down while "in the sap" it is well to leave the tops undisturbed, trimming off the branches only as high up as the log is desired for use as timber. By so doing the leaves in effect act as a suction-pump, drawing the sap upward into the top and drying the wood with remarkable rapidity, a result more certainly attained in the arid or semi-arid than in the moist and humid regions. By this method the writer has seen fir timber dried out within a few days to a degree sufficient for all practical purposes. Where it is employed in the springtime, when the bark is slippery upon the wood, the log will be peeled perfectly of its bark within a few days, and as this removal of the bark eliminates one of the main causes of decay, for the covering absorbs moisture and collects and holds the fungus of dry rot, this period would seem a good time for felling mine timbers when the trees are thus treated. A better period, however, would be during the winter season, when there is a minimum of sap within the tree and the wood is dormant; but the tops should be left with the log that they may draw the sap to themselves in the spring, thereby drying and peeling the timber to a degree.

In the use of timber for support the weight should be resisted as far as possible in line with the grain, for the strength of the timber is materially greater in compression upon the ends of the fibers than transversely across them. Round timber is stronger than that which is sawed or hewn, for such deformation of the original piece cuts the grain of the wood and thereby weakens it. The squared timbers are the more easily shaped and manipulated, and for this reason are in frequent use in underground operations of magnitude.

Because of heat and poor ventilation in underground workings, together sometimes with alternations of dry and damp air, timber supports are subject to rapid decay, which is evidenced by a growth of fungus and a softening or weakening of the wood-fibers. Good ventilation is a necessity to the preservation of timber in such places although similar results are accomplished artificially. Water trickling down the wood tends to wash off the fungus spores and thus acts as a preservative, but in many places this method is impossible of application, and other means to the end are required. In underground operations, and especially

among the mines, the simple question of the preservation of the timber supports against decay is not the only principle involved, but the workings and the timber contained therein should be preserved against fires which have proven so disastrous to mining. Some preservative therefore should be employed that will render timber proof not only to rot but against fire as well, and such results are obtained by the processes using metallic salts, of which zinc chloride has proven to be a cheap and effective antiseptic and is the one most frequently employed. The methods in use are those of steeping the timber for a time in a bath of the solution or, as is generally now done, of forcing the materials into the cells of the wood by hydraulic pressure applied in a closed vessel containing the pieces.

Science of Support.

Invariably in the support of earthworks the primary consideration is that of safety: first for humanitarian reasons, as regards the lives and persons of individuals; and second, for economic reasons, that the workings may be kept open in order to carry out properly the purposes for which they are constructed. Economy should always be sought after, but it is necessary to differentiate between the true and the false economy in carrying out the operations. Preliminary training of a practical nature is an indispensable part of the equipment of the successful operator, to whom not only a general but local experience as well is of large importance; for it is only by actual knowledge in the handling of affairs that he is enabled to judge correctly of the conditions and to apply the proper remedies for overcoming the difficulties that are continually arising. The physical characteristics of the formations in and through which earth-workings are driven determine the methods of procedure, as do also movements of the rock-masses. The general conditions of the formations determine the general plan of procedure, as also do the size and character of the workings themselves, while local conditions determine local and detailed methods of procedure.

All pressure affecting earthworks is due to natural forces, of which gravity acting vertically downward is the fundamental consideration. Indeed it is a fact that all pressures met and to be resisted in earth-workings are intimately connected with and are really a part of the action of the force of gravity. The pressure-forces encountered in underground excavations are due to the resistances offered by the rock-masses to the force of gravity, and they are measured both in amount and direction by the resultants between gravity and the resistances thereto. When gravity is equaled in amount by and opposed in direction to the resultant of the resistances to gravity, which includes not only the resistances offered by the rock-masses themselves but those furnished by the application of natural and artificial supports, then do we have a condition of stable equilibrium wherein a state of rest is existent. When, however, these forces are unequal in amount or where their directions are divergent, then do we have a condition of unstable equilibrium with its consequent movement.

The support of earthworks in general, however, deals with so many uncertainties that it rarely becomes an exact science, and usually it is far less capable of mathematical treatment than is engineering construction, wherein a structure is

dependent not only upon the strength of the materials entering into it, which usually varies even in the same material, but upon an assumed factor of safety that is sometimes also called a factor of ignorance. In applying support to earth-workings the measure of the pressure-forces and their direction as well, is usually indefinite, for both are affected by so many varying and unknown conditions that the application of principles becomes often a matter of judgment, experimentation and renewal.

Fundamental Supports.

The usual supports for particular workings are: for level workings, including passageways and stations, the single piece, the half, three-quarter and full set, either as a square-set or with inclined uprights, the arched and the saddleback set, together with the arch and the pillar. Distance pieces, where necessary, retain the sets in their proper relative positions, longitudinally; for inclined and vertical rectangular passageways, including shafts and the interior workings known as raises and winzes, the usual pieces are the wall-plates, the center-plates and the posts, located as square-sets, together with the close-cribbed plates either of round or squared timber, and the lighter cribbed planking; for vertical round and elliptical shafts, the tubbing of stone, brick, cast iron and wood, together with their bearing rings; and for extraction places, props, and stulls, the half, three-quarter and full sets, the posts, caps, girts, cap-sills, sill-girts, and the single- and double-post sill, of the square-set framing, together with pens and bulkheads.

Of parts of general utility to earth-workings there might be named the blocks and wedges wherewith supports are held firmly in their proper positions; the lagging and spiling, pole, split and plank, for the close or tight and open or loose lining of the workings in both normal and abnormal ground; the single piece, half, three-quarter and full set, the arch and saddleback, together with the crib and pen and bulkhead, for reinforcing supports; and of special parts of general utility there might be named the false timbers and sets that are used to keep the workings open during the placing and replacing of supports, together with those single pieces and other parts that are variously applied in connection with supports.

The shaping of all timber for support is done by the use in some form of the tenon and mortise and the miter, either singly or in combination; and these are fundamental joints however much they may vary in practical detail, as hitches and shoulders, squared and beveled, the joints giving inclination to the parts, gains, grooves, and the various other contrivances in use for enabling the timbers to come together from two or more directions and to connect properly at the joints. In framing supports for particular work the joints should be planned to resist in the strongest manner possible the pressures bearing upon the timbers and especially where such pressures are abnormal, but the information necessary to determine such points may be a matter of previous knowledge or it may be a problem for experiment, to be developed only through the failure of the earlier supports.

Where the framing of timbers for support is a matter of the utmost precision, as in the shaping of supports for rectangular inclined and vertical shafts, all

measures and the marks for cutting are taken either from a particular face of a piece, often in such cases from what will be its top when in position, or, preferably, the marks and measures are taken from a center or datum-line along the center of that which will be the inner face of the timber when located in position, the truest face being always the one selected. The upright lines are thereafter marked at right angles to this datum-line, while those across the timber, from its inner to its outer face, are taken at right angles to the selected inner face. By this method the frames can be so exactly dimensioned that the bottom of a deep shaft will be of exactly the same interior cross-section as is the top or collar.

Both square-sawed and round timbers are sometimes framed by machinery, especially the parts for the square-sets employed in extraction places, but round timbers for the level workings are almost invariably shaped by hand. These are marked by a center or datum-line from end to end, usually by the chalk-twine, and the line across one end of the piece is taken from that end of the datum-line through the center of the timber, its corresponding line across the opposite end being located by sighting a short straight-edge upon the edge of a second straight-edge, the edge of which coincides with the end cross line first marked off. All other lines are measured and marked off at right or desired angles from the above center and cross lines, they being located usually at either end of a timber by means similar to those above mentioned with the idea of bringing all faces and shoulders to correspond exactly with desired planes and angles, that the joint-parts may truly come together when the timbers shall have been placed in their proper positions.

Support of Earthworks.

In the support of surface earthworks, as embankments, walls, trenches and open-cuts, and quarries, the materials of which they are constructed or in and through which they are driven, furnish the only supports required when such materials are of themselves of strength and texture sufficient to support the workings.

An embankment, *per se,* is constructed of indifferently sized materials heaped together to form a bank or mound and dependent for its integrity upon the friction between the different particles of which it is composed. Such a structure made up of various earthy materials, soil, gravel, and crushed and broken stone, will retain its form when the friction between the different particles and, in a lesser degree, the texture of the particles themselves are equal to or of greater moment than is the force of gravity, the weight, which causes them to seek a lower level. This ratio between weight and combined friction and texture is known as the natural slope or angle of repose, and experiment has fixed its value for different materials. When, owing to compression or other causes, the tenacity between the particles themselves increases in amount above that due to friction, then does the natural slope become steeper and the bank partakes more of the nature of a wall. When the tenacity between the particles, or in other words the texture of the materials of construction, becomes possessed of sufficient strength to withstand the weight-pressure to be supported, then the angle of the natural slope may become vertical and the structure becomes a wall that is dependent for its stability upon the strength and mass of its materials of construction.

Walls may be formed of the natural earthy materials or built up by artificial methods. Embankments are often supported by walls of earthy, metal or timber construction, which are then known as "retaining walls."

Trenches and open-cuts are supported either by the natural materials of which their sides are composed, depending either upon the friction between the particles thereof or upon the strength of such materials, and by artificial supports as well. For permanent supports retaining walls built up of earthy materials are usually employed, while for temporary use timber is available, the side materials being retained in position by beams and struts abutting against either wall of the excavation. When the materials composing the sides are unstable and liable to fall away then timber framework, supported by the struts against the walls, is employed, and where the material is too soft for the usual methods of support forepoling or spiling is used.

In quarries, the walls and extraction places are supported either by the natural slope of the ground or the work is done in benches in manner similar to that employed in the underhand stoping of underground workings. These benches may be carried with the line of natural slope of the materials, but their line should never be advanced at a steeper angle.

In underground earthworks the level workings, including passageways and stations, are supported by earthy materials in the form of the natural rock sides and back, as pillars, irregular, round or rectangular, gangway or chain pillars, panel pillars and stump pillars, and by pillar-arches. Artificially the level workings are supported by earthy materials, as stone in blocks, broken and crushed (as masonry, dry and wet, in walls, arches and stulls, and as waste-filling and waste-stowing), brick (masonry, wet, in walls, arches and pillars), and cement (in walls, arches and pillars, or applied as a thin coating in successive layers); by metallic supports, in which the single piece, the half, three-quarter and full sets, and all parts thereof, the arched, the cylindrical and the oval workings are formed of structural iron and steel plates and beams; by timber, of which the single piece, the half, three-quarter and full sets, the arched and saddleback sets, are framed as special parts for specific purposes; and by combination supports, as of earthy materials and metal or timber and of metal and timber.

Of the inclined and vertical passageways the inclined shaft, of one, two, three and four compartments, is supported by the earthy materials in the form of the natural rock in place and, locally, as side pillars. Artificially the inclined shaft is supported by stone, brick and cement, walls and pillars, with or without cap-plates; by wall-plates, centers and posts of structural iron and steel; and by timber supports in the form of wall-plates, center-plates, posts, cap- and sill-plates, and as girts, with all parts framed, located and aligned with exactness.

The vertical round and elliptical shafts are supported by the earthy materials in the form of the natural rock in place, and artificially by stone, brick and timber tubbing, with bearing rings and exterior coffering.

The vertical rectangular shafts, single and double width, of one, two, three, four, five, and six compartments, are supported by the natural rock in place, in which case framing is often put in for the purpose of carrying the guides for cages and skips; and artificially by metallic supports in the form of wall-plates,

centers, and posts of structural iron and steel, and by timber supports in the form of buntons, wall-plates, center-plates, and posts, with all parts framed, located and aligned with exactness.

Raises and winzes, which are the interior workings passing from level to level, usually within the deposits containing materials of economic value, are often supported by timber frames similar to those of the inclined and vertical rectangular shafts, but sometimes the supports of these workings are made a part of the usual framing of the extraction places within which they frequently form passageways.

Of extraction places, the horizontal deposits are supported by earthy materials in the form of the natural rock in place, as pillars (irregular, round or rectangular, shaft and gangway pillars, panel and boundary pillars), and as pillar-arches. Artificially such deposits are supported by the earthy materials as stone in blocks, broken and crushed (masonry, dry and wet, in the form of walls, pillars, in pens and stulls, and as waste-filling and waste-stowing; brick (masonry, wet, as pillars and arches and walls), and cement as walls and pillars; metallic supports in the shapes of hollow cast cylinders of iron and steel and certain structural beams that may be used as props; timber supports, wherein round timbers are employed for use as props and are likewise used in crib and pen, squared timbers being also used in the open pen; and combination supports, in which waste-filling and stowing is used in connection with the timber pen.

Within the inclined and vertical deposits and masses, as regards the earthy materials, the natural supports to the roof and sides and to the hanging- and foot-walls are furnished by the natural rock in place, either that of the exterior rock or that composing the deposits that is left in position in the shape of pillars of various dimensions and forms, the artificial earthy supports being those earthy materials that are employed as waste-filling and waste-stowing within the open places. Timber furnishes the greater part of the artificial supports in the extraction places of the inclined and vertical deposits and masses, wherein it is used in various forms. The stull is but the adaptation of the prop to the uses of the inclined and vertical deposits, and similarly its province is to support the weight of the hanging-wall upon the foot-wall. In steeply inclined deposits, where either the hanging- or foot-wall is weak and inclined to fall away without intermediate support, a post is often placed beneath the stull to hold it in place and to support intervening ground between two stulls, the post being supported at the other extremity upon the stull beneath, thus forming the three-piece or three-quarter set, the full or four-piece set being a similar adaptation of the stull with supporting posts beneath either end to the set frame within the extraction places and employed when the rock of both walls is of too weak a nature to stand without such support.

A still further development of the set to the uses of supporting the extraction places brings us to the square-set, now so generally employed among the metal mines for the support of wide veins and the irregular mass deposits. Here the system applies the unit to the support of excavations, and this unit consists of the single square set, the parts being so framed that the set may be placed in position wheresoever it may be needed, either singly and alone or in combinations large

or small and in any direction, dropping the units in following upward with the hanging-wall of the deposit or in leaving a pillar in position in barren ground, and adding units laterally with the inclination or dip of the foot-wall, the system expanding laterally, longitudinally and vertically with the excavations as desired. These units consist of hollow blocks or squares made up of framed pieces of timber of desired dimensions, those upon the bottom or sill floor being made up of single- and double-post sills, sill-girts, posts, caps and girts, while the units or sets upon the floors above are composed of posts, caps and girts, the cap and girt of the set on the floor beneath forming the sill timbers of the upper sets. In following upward along the foot-wall and as a means of adding units exterior to the system laterally a combination of sill and cap, called the cap-sill, is employed, which is usually supported upon the solid material of the wall and which in turn supports the units above. Almost invariably the units of the square-set system are vertically placed within the deposits, but there are instances where the placing of the timbers at an inclination and along the line of dip of the vein has been successfully done and possibly more satisfactorily than the vertical method would work to the desired end because of the characteristics of the deposit. Cribbed pens and bulkheads are sometimes constructed within the extraction places, and they are often invaluable as a means of supporting the rock overhead.

The combination supports as applied to these classes of deposits comprise the use of timber and the earthy materials, especially the broken, crushed and disintegrated stone that is employed as waste-filling and waste-stowing and which is filled in or built up simultaneously with or subsequent to the processes of locating in place the timber systems.

Special Equipment.

The surface equipments for level workings are the portals for adits and tunnels; and for inclined and vertical workings, the collar or top arrangements of vertical and inclined shafts, the tower-sills, for supporting the upper sets of vertical rectangular shafts in loose material until firm ground is reached with the supports, and the methods of locating the shaft collars to any desired height above the level of the surrounding plain, either by the regular shaft framing or by the more substantially built up cribbed frame that is filled and rendered solid by waste and broken stone.

The underground equipment consists of: for the level workings, the gates and gateways of chutes for the loading of cars in the passageways, and for stations it consists of the rooms for the location of pumping plants, the sump-tanks and lodges for collecting water at the various levels, and the port ropeways above for the purpose of giving added height to shieve-wheels within the shafts for sinking purposes; for inclined and vertical passageways, of shafts, the guides of timber and of rope for carrying and holding in proper position therein the cages and skips and buckets, the pentice of natural rock and of timber bulkheads within the shaft for the protection of the men engaged in sinking, the timbers and iron plates for protecting the shaft supports during the blasting of hard rock in sinking, and the hanging bolts for retaining the shaft sets in position during the processes of locating and blocking them in place; for the extraction places, the methods of

supporting waste-filling above the drifts by drift sets and by stulls, and in the square-set system, the methods of constructing bends and turnouts in the drifts of square-set timbers by swing-girt, by turning-sheet, by enlarged junction-set reduced to normal size above, by angle-braced support over the drift, and by the independent-drift sets, and the methods employed for making connections between stopes in narrow and in wide deposits and of supporting the waste-filling above during the process; and as regards the question of special equipment there are the methods of underground storage by ore and waste chutes, by ore bins, and of storing waste rock in the shaft during sinking.

Manipulation of Supports.

As regards the handling of supports and their transportation underground there are the methods commonly employed in the horizontal workings, in the level passageways and extraction places; and in the inclined and vertical workings, the methods used in shafts and in raises and winzes and those employed within the extraction places of deposits.

As regards the locating and aligning of supports: in connection with the level workings there are the ordinary methods of procedure in normal ground and the special methods employed in soft and heavy and in running ground, both in passageways and stations; in connection with inclined and vertical shafts of all shapes and sizes there are the ordinary methods of procedure for locating and aligning the parts in normal ground and the special methods employed in soft and heavy and in running ground; and in connection with extraction places there are the methods of locating the props and stulls, of building up the cribs and pens, of placing the sets, and the ordinary and the special methods of procedure in building up the square-set units to suit the demands of the occasion, dependent upon the normal and abnormal characteristics of the ground.

As regards the reinforcing of supports: in connection with the level workings, for both passageways and stations there are the inner reinforcing sets, the doubling-up sets, the inner and exterior saddleback and arch, and the exterior pieces, as caps and posts; in connection with inclined and vertical shafts there are the exterior plates and the bulkhead plates; and in connection with extraction places, for horizontal deposits there are the prop batteries, for inclined and vertical deposits there are the wall-posts with stull and stull batteries, and for wide veins and mass deposits in connection with square-sets there are the three-quarter and full reinforcing sets, angle-braces variously applied, the combination of reinforcing set and angle-brace variously applied, the brick-work bulkhead and the solid bulkhead..

As regards the easing and relieving of supports, in heavy and in swelling ground: in connection with the level workings, for passageways the exterior easing-cap and post with strut and used with open lagging, the exterior-triangle easing set with open lagging, the spreading-post set with open lagging, and for stations, the exterior cap and post with struts and open lagging, and the exterior saddleback with open lagging; and in connection with inclined and vertical shafts, for inclined shafts there are the exterior cap-plate and the exterior post-plate

with struts, and for vertical rectangular shafts there are the exterior stringer easing-sets and the exterior wall-plate easing-sets.

As regards the repairing and replacing of supports: in connection with level workings, there are the methods employed to support the ground during the operations, those used in removing the old supports and in placing the new supports in position; in connection with inclined and vertical shafts, there are the methods employed in supporting the ground during the operations and those used in removing the old supports and in placing the new supports in position, the methods of bringing the shaft into alignment and the wall-plates to their proper relative positions, horizontally or otherwise, and the methods of handling caved ground in the vicinity of shafts; and in connection with extraction places there are the methods to be employed in recovering lost and caved ground.

ALLOYS AS SOLUTIONS.[1]

By John Alexander Mathews.

For a student either of metallurgy or history, it is not necessary to adduce evidence to show that the knowledge of how to extract metals and to fit them for use is of great antiquity. The people living long before the Christian era knew that mixed metals often possessed properties very different from those of the constituent metals, and they applied this empirical knowledge to the reduction of metals from their ores and to the production of alloys from the metals thus obtained. Nevertheless a knowledge of the molecular constitution of these substances was lacking until within a very few years, and if any of the scientists of even as late a day as the first half of the last century had any conception of the truth in regard to alloys, the means of experimentally confirming their speculations had not yet been evolved. But had the means been available, it could not be expected that the difficult problems of molecular physics, which a study of alloys involves, would have been solved until a molecular theory of the constitution of all matter had been enunciated, nor could it have made any progress before the period of chemical reform begun by Lavoisier, the period of quantitative investigation. But only recently, even in this period in which we still labor, have the relations of physical properties to chemical constitution attracted both chemists and physicists to concerted activity, and in this field of investigation alloys were slow to yield fruitful results. Physical and chemical methods of research, which were entirely satisfactory when applied to bodies of other kinds, failed utterly to afford a rational explanation of the molecular conditions existing in alloys. The solution of these problems required new methods and new apparatus. Fortunately, these are at hand; they have been slowly evolving and the past decade has been most fruitful of results.

With few exceptions, the great leaders in this new branch of applied science belong to the contemporary school of English and French physicists and metallurgists, a résumé of whose achievements is given in the pages that follow.

A most potent factor in this recent progress has been the official recognition of the necessity of study along these lines. More than 10 years ago the Institution of Mechanical Engineers of Great Britain appointed an Alloys Research

[1] Reprinted with some modifications from the *Engineering and Mining Journal*, Dec. 21 and 28, 1901.

Committee, which receives financial assistance from the institution; five reports have been published by it, and a sixth report is, I believe, about to appear. It is in connection with the work of this committee that Sir William Roberts-Austen, his pupils and the co-workers of his staff have produced such excellent work, especially in pyrometry and in explaining the complicated changes, allotropic and otherwise, which steel and cast iron undergo.

The practical operations of annealing, tempering, hardening, etc., can now be conducted upon a scientific and rational basis. The effects of thermal operations can be predicted accurately and desired results obtained unfailingly. It would be too much to say that all this is due to this committee alone; but if we include also the committee of the British Association, appointed to investigate the nature of alloys, of which Mr. Neville is chairman, and the "Commission des Alliages," of the Société d'Encouragement l'Industrie Nationale, as also sharing the honors of recent great advances in both our theoretical and practical knowledge of alloys, then we have recognized the three most prolific contributors to our knowledge of metallic mixtures. While giving these official bodies full credit for their discoveries, we would not detract in any way from the honor due to many individual workers not connected with committees who are scattered through many lands. It is safe to say, however, that the larger results of the concerted work of committees has had a stimulating effect upon the private worker. One of the greatest evidences of appreciation of the necessity for research in connection with alloys is that nearly every railroad in France and many metallurgical concerns contributed to sustain the work of the "Commission des Alliages."

The purely scientific reasons which have made possible the recent advances in alloys research seem to me to be: (1) *An increased knowledge of solutions.* For this we are undoubtedly indebted in very great measure to the great Dutch and German physical chemists—Van't Hoff, Roozeboom, Ostwald, Nernst and others. (2) *The development of metallography.* This seems to have originated with Dr. Sorby, of Sheffield. Although he wrote about the microstructure of meteoric iron as early as 1864, the progress of metallography was very slow. Only within the past 10 or 15 years have even metallurgists begun to recognize what a valuable aid to research it is and unfortunately the manufacturers have not yet given it just recognition. Recent progress in this branch of applied science is most closely attached to the names of Stead, Martens, Osmond, Le Chatelier, Charpy, Roberts-Austen, Howe and Sauveur. (3) *Improvements in pyrometry.* The study of metals, alloys, furnace reactions, etc., was retarded for many years because of the lack of the suitable means of measuring accurately very high temperatures. Such means as have been available for these purposes in past years were not suitable for general use around shops and metallurgical works and were inconvenient even for the laboratory. Now, however, there are at least two reliable pyrometers which are conveniently manipulated and lend themselves readily to accurate measurements of high temperatures. The Siemens electrical resistance pyrometer, as perfected by Callendar and Griffiths, gives wonderfully accurate readings within certain limits. For use both in the laboratory and in the factory it does not seem as popular—in the United States at least—as the Le Chatelier thermo-electric

couple. The very accurate work of Messrs. Heycock and Neville is perhaps as good a recommendation for the possibilities of the electrical resistance pyrometer as can be cited. The particular advantages of the thermo-electric couple as applied to alloys research are—its accuracy at high temperatures, its ability to be used with very small masses of heated substances, and, indirectly, its ability to be used in conjunction with a photo-autographic recorder, as has been so well demonstrated by Sir William Roberts-Austen.

Crystalline Growth in Metals.—Before entering upon the consideration of alloys, it may be well to note a few general properties of metals, particularly their mode of crystalline growth and the effects of strain. To both of these subjects Prof. Ewing and Mr. Rosenhain have given much attention and have explained the phenomena of these operations very clearly. They state that all solid metals are crystalline, even though when examined by the microscope the individual crystals or crystalline grains may not present a simple geometrical outline. The essential point is that the particles composing the mass of a crystal lie in one direction, *i.e.*, have the same plane of orientation. Mr. G. T. Beilby read a paper at the meeting of the British Association held in Glasgow, September, 1901, upon "The Minute Structure of Metals," and cites evidence to show that he has identified minute spicules or scales showing remarkable uniformity of size and appearance in metals of all the leading groups. These under mechanical treatment may be converted into transparent glass-like substance and may again reappear as spicules unchanged in size. The diameter of the scales is estimated to range from 1-300 to 1-400 of a millimeter. The metals examined by Mr. Beilby include gold, silver, platinum, cobalt, nickel, chromium, iron, copper, lead, bismuth, antimony, tin, cadmium, magnesium, aluminum, zinc, and sodium. Brasses and bronzes were also examined. The author says that the crystalline faces and cleavages of such metals as antimony, bismuth and zinc exhibit the same features as the softer and more malleable metals, being covered with a film of transparent metal, while in fractures at right angles to cleavage planes, scales are distinctly seen. Mr. Beilby's conclusions are: "The persistence of these minute scales or spicules under all kinds of mechanical and thermal treatment, the remarkable uniformity of their size and appearance in metals of all the leading groups, their disappearance into the transparent form and their reappearance again, apparently unchanged in size or otherwise, seem to afford fair ground for the conjecture that they are in some way definite units in the structure of metals."

It may be that these are the "units" whose arrangement in certain definite orders constitutes crystals, and this similarity of disposition of particles is what constitutes orientation. Prof. Ewing explains crystallization in metals in this way: the formation of crystals must be assumed to start simultaneously at many points. The crystals grow until they touch one another, and, although individual crystals are similar, it is not necessary that the corresponding axes of any two of them lie in the same plane. No doubt each crystal is of perfect form so long as it is free to grow in all directions; when the crystals touch, their symmetrical growth is hindered, but the orientation of the subsequent particles which attach

themselves is not changed. It is for this reason that orientation[2] rather than geometrical outline is considered the essential feature of crystalline growth. In the case of commercial metals, more or less impure, the impurities are cast out by the growing crystals, and being in fact alloys of the admixed metals with the still fluid principal metal, they have a lower melting point than the pure metal. Therefore, they solidify last and form an investing cement which holds together the primary crystals.

The Effect of Strain.—When a polished metal is subjected to strain there is no change noticeable until the stress exceeds the elastic limit. When, however, the plastic stage is reached, there will appear dark lines more or less perpendicular to the direction of stress. This, Prof. Ewing[3] says is not due to fissuring, for by changing the direction of the rays which illuminate the specimen under observation from vertical to oblique, it will be seen that the erstwhile dark lines appear light, while the background has changed from light to dark. Fissures would not have reflected light in any case; the permanent elongation is due to slipping of the components of the crystals past each other. That is, the surface which was originally plain, presents, after stress has been applied beyond the elastic limit, the appearance of minute steps. It is as though one should take a pack of playing cards with their ends presenting a smooth surface. Now if the thickness of the pack of cards were one inch, and the pack were bent, the end surface of the pack would measure more than an inch and would consist of little steps, not only the ends, but also a part of the flat surfaces of the cards being exposed.

In the case of metals, the slip-lines need not necessarily lie in one plane. As many as four sets of parallel slip-lines have been noticed by Prof. Ewing. Mr. William Campbell worked upon this phenomenon independently at about the time that Prof. Ewing was making his preliminary observations. He experimented with tin, while Prof. Ewing worked chiefly with lead, and it is interesting to note how completely their results agree.

The growth of crystals from a solidifying molten mass is easy to comprehend, but why is it that crystals grow in a solid mass of metal not only by annealing but even at ordinary temperatures? Big crystals actually consume the little ones. A bit of rolled tin which was allowed to stand for eighteen months at ordinary temperatures in the laboratory showed a marked change in appearance, due to growth of its crystals. If a specimen of tin is put upon a hot plate and heated to, say, 200°C. for ten days, a growth such as is shown in Fig. 1 is obtained, which shows the tin before and after annealing. This photograph is one of Mr. Campbell's, and is a little under actual size. It also shows very well the different orientation of the crystals. In fact, the growth of these crystals was so rapid that a micro-section through them reveals slip-lines, probably due to this rapid growth. The fact that the slip-lines are only parallel within the same crystal seems to confirm this view, for, had the stress been applied longitudinally by artificial means all the slip-lines would have been more or less normal to the direction of the stress.

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[2] Howe. *The Metallographist*, January, 1902.

[3] Ewing and Rosenhain, *Philosophical Transactions of the Royal Society*, CXCIII., p. 353, or *The Metallographist*, 1900, p. 94

Fig. 1. Tin, Before and After Annealing.

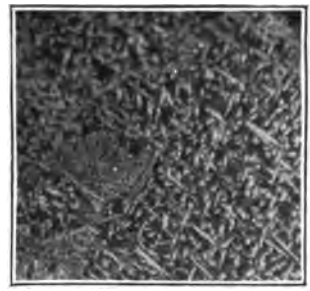


Fig. 4. Change in Structure of Alloy 88.7 % Cu. and 11.3 % Al. when slowly cooled to 500° C.

Fig. 1 A.

Fig. 1 B.

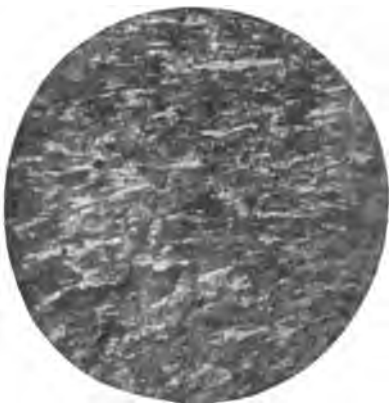


Fig. 1 C.

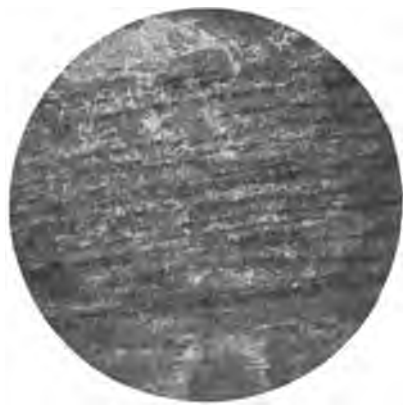


Fig. 1 D.

Slip Lines in Steel Resulting from Strain.

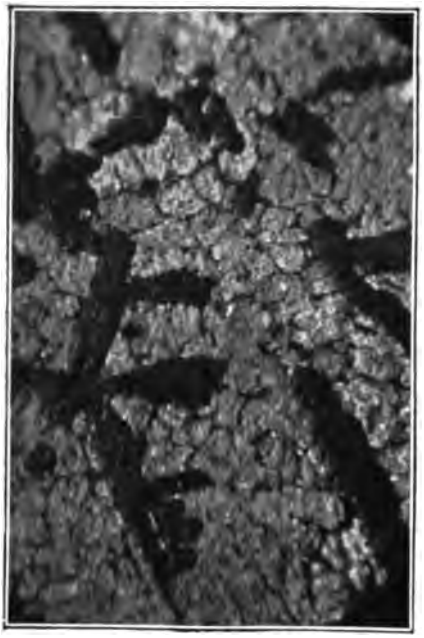


Fig. 10. 20% Sb, 80% Al x 33 diameters, oblique illumination, shows crystals of Sb Al in granular ground mass of nearly pure Al.

Fig. 12. 82% Sb, 18% Al x 16 diameters, vertical illumination. This photograph shows nearly pure Sb Al.

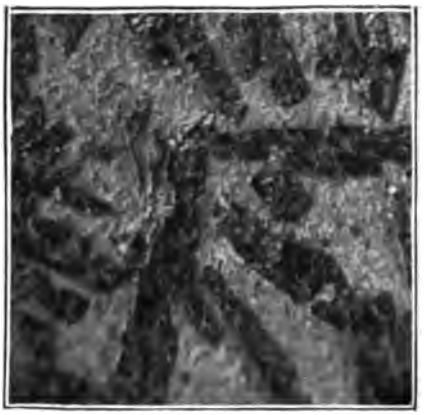


Fig. 11 50% Sb, 50% Al x 33 diameters, oblique. Crystals of Sb Al increasing in size and amount, ground mass decreasing.

Fig. 13. 85% Sb, 15% Al x 33 diameters, vertical illumination. We have passed the summit of the curve; the ground mass of aluminum has disappeared, and some free antimony is seen.

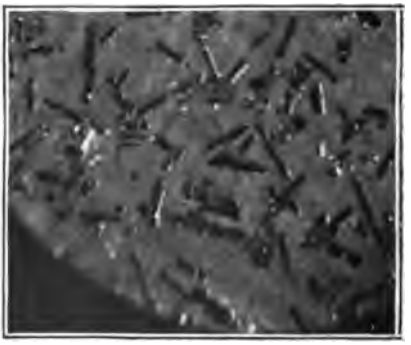


Fig. 14. 95% Sb, 5% Al x 33 diameters, oblique. Sb Al crystals diminishing in quantity, and ground mass of Sb—probably containing a little Sb Al in solid solution—is conspicuous.

With regard to the growth of crystals in strained metals when they are subsequently warmed, Mr. Rosenhain has offered this explanation: In strained metals the layer of enveloping alloy surrounding the separate crystals becomes broken, and the difference of potential between the metal and the alloy set up by electrolytic action causes a solution of the crystal on one side of the alloy and a deposit on the adjoining side. This he verified by the following experiment: Two pieces of lead were scraped clean and welded by the application of great pressure. A micro-section through the weld showed that the crystals in neither piece extended across the weld. When, however, between two such surfaces a little powdered tin was sprinkled and pressure applied, a micro-section revealed that electrolytic action had taken place and that crystals from either side extended across the weld. Ingenious as is this explanation, yet I am not certain that the proof is conclusive. If I mistake not, at the last Cantor lectures before the Society of Arts,[4] Roberts-Austen and Rose showed crystals of gold extending across a weld, although the purest standard gold was used in the experiment. In fact long annealing of this gold obliterated the weld almost completely.

The effect of strain is very beautifully shown in the accompanying figures.[5] A piece of very pure steel—0·035% C—was bent double in the cold. The magnet-shaped bar was then sectioned through the middle, parallel to the plane of bending. Upon polishing and etching it was seen that the ferrite (pure iron) crystals on the inside of the bend showed the effects of compression. The crystals upon the outer edge being under great tension were stretched, while the crystals near the center, or so-called neutral area, were practically unchanged in shape, although slip-lines may be faintly discerned running through them. Figs. 1*A*, 1*B*, and 1*C* show these three conditions, but the slip-lines are much better shown in Fig. 1*D*, which represents the neutral area of a similar rod of 5% nickel steel (0·2% C). The slip-lines traversing the large grains of ferrite containing nickel and the surrounding pearlite are plainly shown.

Freezing Point of Metals.—With water and many other liquids we know that it is quite possible to lower the temperature to a considerable amount below their freezing-point without the separation of any solid. On the other hand, it is not known that any solid may be heated above its melting-point without becoming a liquid. The property first mentioned is known as surfusion. On account of this phenomenon it would be theoretically preferable to determine the melting rather than the freezing-point of metals, but practically this is a very difficult task, while freezing-points are in most cases easily determined and surfusion need not interfere with their accuracy in the least, for when solid matter begins to separate from a pure liquid thus cooled, the temperature rises rapidly to the true freezing-point and remains constant until the whole mass is solid. Sir William Roberts-Austen cites an instance in which tin was cooled 20°C. below its freezing point without solidification, and I have frequently observed the same result in tin and some other metals; antimony is especially apt to show surfusion. I have repeatedly observed antimony show thirty-five degrees of surfusion, *i.e.*, the

[4] *Journal of the Society of Arts*, 1901, p. 851.

[5] Mathews, *Journal of the Iron and Steel Institute*, Vol. I., 1902.

metal, still molten below 600°C., suddenly becomes heated again to 632°C., and remains at that temperature until completely solid.

In working with metals the first point at which solids separate is taken as the freezing-point, and surfusion need not obscure this point, particularly if an autographic record of the cooling curve is taken. If we plot a typical cooling curve of a pure metal, using temperature and time as the co-ordinates, we obtain a curve represented by *A B*, Fig. 2, having two very distinct angles, while a portion is horizontal, *i.e.*, the temperature remains constant during the whole period of solidification. If surfusion takes place, and it is more common in pure metals than in alloys, the curve *A' B'* represents what happens. The temperature falls below the real freezing-point, and then rises abruptly to that point and remains constant as in *A B* until solidification is complete. In impure metals—and since the impurities are usually metallic, they are really alloys—the temperature does

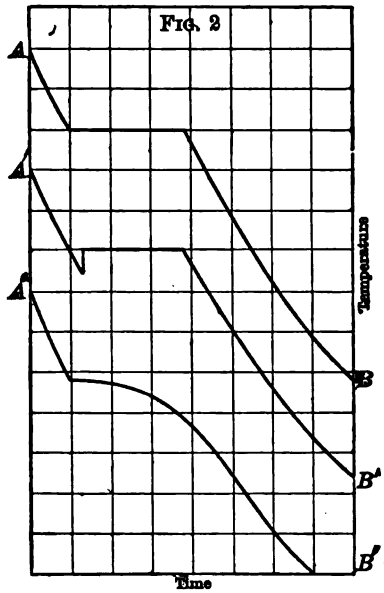


FIG. 2

not remain constant at all, but a decided change in direction is noticed indicating the point at which solidification commences as shown in *A'' B''*. The greater the amount of impurity, the more rounded will appear the cooling curve. Since these are really the curves of alloys and solid solutions, they will be explained at greater length subsequently. This third type, *A'' B''* is introduced here because it shows that the nature of the cooling curve gives us a clue as to the purity of the metal under examination. To explain surfusion, we need only remember that fusion is always attended by absorption of heat and solidification by evolution of heat. When a "surfused" substance begins to solidify it disengages heat and the temperature rises until the melting-point is reached. No further rise takes place because at this temperature only, liquid and solid are in equilibrium. Any further change of liquid to solid or solid to liquid must be effected by abstracting or adding heat. In practice, either heat is lost

by radiation and the whole mass solidifies, or is supplied by artificial warming, and the whole mass becomes liquid.

Binary Alloys.—Having now noted some of the properties of pure metals we may next consider what happens when two metals are melted together. We shall not at this time consider tenary or more complex alloys. The first thing noticed upon melting together two metals is that (1) they mix in all proportions, or (2) they do not. In the first instance, under proper conditions an approximately homogeneous solid mass is likely to result when the molten alloy is cooled. In the second case, on cooling it will be found that the metals have separated into layers, the lighter metal on top. Each layer, however, will be found upon analysis to contain a certain amount of the other metal in solution, just as ether and water dissolve small quantities each of the other. As between certain metals and solid non-metallic elements it seems as though they were absolutely insoluble in one another at ordinary temperatures, although they may be quite soluble at high temperatures. For example, M. Moissan tells us that metals of the platinum group readily dissolve several per cent. of carbon at the temperature of the electric furnace, but cast it *all* out as graphite on cooling. It has not yet been determined whether the graphite, which separates in cast iron, contains iron or not. It seems to me that we shall come nearer the truth if we consider such cases as solutions of almost infinite dilution, rather than as absolutely pure metal or non-metal.

We have just spoken of metals dissolving metals, and it is this conception of alloys as solutions—solid solutions—that has been steadily progressing in favor in recent years and which we hope both to explain and to confirm by citing the results of the experiments of many investigators. Very striking analogies exist between ordinary solutions and alloys; in fact, to point out these similarities is to give our present conception of the constitution of alloys.

Solid Solutions.—This expression is due to Van't Hoff, but Roberts-Austen has done most to make it familiar to metallurgists. Our text-books upon physical chemistry contain much information upon the subjects of solutions of gases in liquids, liquids in liquids, and solids in liquids, but are for the most part silent upon the subject of the solutions of solids in solids. The extension of our knowledge upon this subject is very recent and mostly confined to technical periodical literature of recent dates. Prof. Roozeboom and his pupils have carried on researches upon the nature of fused mixtures of salts and their behavior upon cooling. This work throws considerable light upon the problems of chemical equilibrium in alloys. As defined by Sir William Roberts-Austen a solid solution is "a homogeneous mixture of two or more substances in the solid state." In metals no one has worked as yet with non-crystalline mixtures, and solid solutions of metals when crystalline are solid "isomorphous mixtures," or "mixed crystals." The use of these three terms to denote one condition is confusing and unnecessary, and as objections exist to the last two synonyms, their use should be discontinued. The term "mixed crystals" is particularly apt to convey a wrong impression to one who sees this name for the first time, especially if it is unaccompanied by a definition or explanation.

Mr. Stead, in the *Journal of the Iron and Steel Institute,* 1900, classifies solid solutions as follows:—

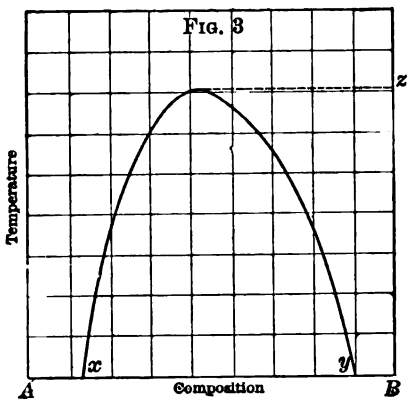
(1) Those in which one constituent of an alloy in crystallizing retains a portion of the other homogeneously diffused through its whole crystalline mass.

(2) Those in which during crystallization the central portion of the crystals contains less of the dissolved substance than their external boundaries.

(3) Those in which the metals form a definite compound, which is retained in solid solution in the excess of metal or metals. I should like to add that the "compound" may be the "solvent," in the sense in which those terms are here used.

The condition described in (2) is that of an unstable system. Crystallization has taken place more rapidly than diffusion, and in such cases where crystals are not of uniform composition from center to outside complete homogeneity could probably be obtained by annealing. Mr. Stead adds a fourth class. (4) Those in which the non-metallic elements form definite compounds with a portion

FIG. 3



of the dissolving metal that remains in solid solution. This class would include the property of metals, such as iron and copper, to dissolve a portion of their oxides. Such solutions have been little studied, but E. Heyn[6] finds that the fusibility curve for solutions of cuprous oxide in copper is of the type of the freezing point curve of salt and water and shows a eutectic.

In the case of metals which do not mix in all proportions, the two layers formed on cooling consist of solid solutions belonging to one of the types just mentioned. Some of the pairs of metals which do not mix in all proportions at ordinary temperatures are Zn-Pb, Zn-Bi, Pb-Al, Bi-Al, Cd-Al. These have all been studied by Dr. Alder Wright,[7] and Mr. Campbell[8] and myself have repeated and verified a part of Dr. Wright's work upon the aluminum alloys. In all these pairs of metals the relative solubility is a function of the temperature; therefore, it appears likely that at some temperature solubility is complete. Accordingly we may represent the condition existing between these and any other similar pairs of metals by a "critical curve" (Fig. 3). *A* and *B* are the metals

[6] *Bulletin de la Société d'Encouragement de l'Industrie Nationale*, 19 1 (2), p. 276.

[7] *Proceedings of the Royal Society*, 1889–1893.

[8] "The Alloys of Aluminum," *Journal of the American Chemical Society*, 1902, p. 253.

which are not entirely miscible at ordinary temperatures, but which form layers. The metal *A* contains the quantity of *B* represented by the space *Ax* on the composition line. Similarly the metal *B* contains *B y* per cent. of *A*. With increasing temperature the mutual solubilities increase, and at a temperature *z* there is but one solution. Alloys represented by percentage compositions, which fall outside the curve *x z y* are homogeneous. Those whose composition is represented by percentages within *x z y* may be considered as similar to emulsions at all temperatures below the curve at which they are liquid. They are incapable of remaining homogeneous. To such alloys, Sir George Gabriel Stokes gives the name of *ideal* (*i.e.*, unreal, imaginary) alloys while those falling outside the area *x z y* he calls real alloys. The distinction between such pairs of metals as form separate layers on cooling, and the more or less laminated or striated structure produced upon solidification of eutectic alloys, will be pointed out later.

Molecular Freedom in Solids.—It must not be supposed that because certain bodies are designated "solid" that entire absence of molecular mobility is implied. Such an idea is far from the truth; the difference in mobility of the molecules in "solids" and "liquids" is one of degree only. On the boundary between solids and liquids substances are said to be viscous or plastic. Just as crystals of a soluble salt placed in contact with water tend to become dissolved and uniformly distributed throughout the solvent, so metals, even at normal temperatures, tend to form uniform solutions; this tendency, though slight, is none the less real. Metals even tend to evaporate and to be surrounded by their own vapor. Robert Boyle thought that "even gold" had its "little atmosphere." From analogy with salt solutions we may suppose that one metal dissolved in another shows a small expansive tendency to escape from solution; in other words, exhibits osmotic pressure.

Prof. W. Spring, of Liege, demonstrated the fluidity of solids, if I may use that expression, in his famous experiments upon the behavior of metals under exceedingly high pressures—ten thousand atmospheres, more or less. He showed that by pressure alone:—

(1) Metals can be made to flow. The familiar operation of striking coins illustrates this property of metals and alloys. A medal has recently been struck in steel.

(2) Solids, both metals and salts, like liquids and gases, possess perfect elasticity and suffer no permanent diminution in volume by pressure. Strain, torsion or bending may produce permanent deformation in a metal or alloy, but there is no limit of elasticity in regard to diminution in volume, for when the pressure is removed the solid assumes its original volume. An exception to this is cited by Prof. Spring in his next generalization, *viz.*:—

(3) Allotropic changes may result from pressure. Prismatic sulphur becomes octahedral sulphur and amorphous arsenic becomes crystalline. In both these cases the second allotropic form is denser than the first, and from these and other experiments Prof. Spring argues that allotropic transformations by pressure show that matter takes the state which corresponds to the volume it is obliged to occupy. Moissan's brilliant experiments upon the production of artificial diamonds illustrates this principle.

(4) Metallic filings are converted by pressure alone into solid masses, just as if they had been fused. Similarly mixed filings yield alloys: *e.g.*, brass was produced by compressing clean, flat surfaces of zinc and copper. Reactions of double decomposition between dry salts and the production of the highly colored regulus of Venus (Cu_2Sb) show that not only intimate agglutination, but also chemical combination may take place between bodies in the solid state. I have confirmed some of Prof. Spring's results, but was unable to produce several typical intermetallic compounds as Au Al_2, Sb Sn, Sn Cu_4, etc.

Prof. Roberts-Austen has demonstrated the fact of molecular mobility among solids in a prolonged series of very beautiful experiments upon the diffusion of gold into lead at temperatures from 250°C. down to the ordinary temperature. Graham showed long ago that gold diffusing into molten lead, tin, etc., obeyed Fick's law,

$$\frac{dv}{dt} = K\frac{d^2v}{dx^2}$$

where x is the distance through which diffusion takes place (against gravity), v is the concentration of the diffusing metal, t = time, and K is the diffusion constant, *i.e.*, the quantity of metal in grams diffusing in unit of area (1 cm.^{2}) in unit of time (1 day) when unit difference of concentration (in grams per cm.^{3}) is maintained between the sides of a layer 1 cm. thick.[9] That is, metals dissolve in metals, just as salts dissolve in water. Were it not for the operation of this law it would not be such an easy matter to prepare homogeneous alloys. For instance, with relatively little stirring and relying upon diffusion, it is very easy, according to Sir William Roberts-Austen to make 1,200 oz. of coin gold alloy, the first and last pourings of which shall not differ by more than 1-10,000 part in fineness. The idea that interchange of matter can take place between solids is not a new one, as is shown by the cementation process of the ancient Hebrews by which gold was purified.

The experiments upon the diffusion of gold into solid lead, which Roberts-Austen has recently reported to the Royal Society, may be summarized as follows:—

Gold placed in the bottom of a tube filled with lead and maintained at 250°C. (79° below the melting point of lead) appeared at the top in notable quantities in a month. At 100°C. the rate of diffusion was 1-100,000 of that in fluid lead, and in solid lead at the ordinary temperature, allowed to stand in contact for four years, unmistakable signs of diffusion took place, but its rate was such that in one thousand years the diffusion would equal that taking place in one day in lead just molten.

Fig. 4 shows another sort of change which may take place in solid materials. An alloy containing 88·7% Cu and 11·3% Al corresponds closely to the compound Cu_9Al. It should, therefore, appear almost homogeneous, and so it does when quickly cooled. When slowly cooled, however, it changes at 500°C., or nearly 600° below its freezing point, and presents the variegated appearance shown in Fig. 4, which no metallographist would care to call a typical structure for an intermetallic compound.

[9] See Roberts-Austen, Graham Lecture before the Philosophical Society of Glasgow, 1901.

We apply practically the phenomenon of molecular mobility in solids in all annealing operations. By this means the ill effects of strain due to sudden cooling are remedied, and equilibrium is established in articles of metal, glass, enamel and other materials. The rate of diffusion of gold in lead at the various temperatures is an indication of the rapid increase in molecular mobility which results by very moderate increments in temperature. This knowledge is applied whenever we resort to moderately elevated temperatures in all sorts of annealing operations. Steel is very sensibly annealed at temperatures more than 1,000°C. below its melting-point.

Behavior of Binary Alloys during Cooling from Fused State.—It has been stated that metals may or may not mix in all proportions. If they do mix, we may further distinguish those cases in which (1) chemical combination does not take place, and (2) those in which chemical combination does take place, and one or more intermetallic compounds result. The reality of the existence of intermetallic compounds is undoubted, yet, so far as I know, no mention is made of them in the standard books on general chemistry. Indeed very little is known in regard to the nature of the affinity between metals. It does not seem necessary to suppose that the laws applying to combinations between elements or radicals which are relatively electro-positive and electro-negative be equally applicable here; and our conceptions of valency are seriously shattered if we attempt to reconcile them to intermetallic compounds. The difficulties in studying intermetallic compounds are very great, because they are troublesome to isolate, and in many of their properties they resemble the metals. Frequently, too, they are quite unstable and show marked dissociation. Chemical methods of studying them are of very limited application; filtering off solidified intermetallic compounds from a still fluid metallic mother liquor at high temperatures presents extreme difficulties and volatilization of the excess of solvent metal is rarely applicable. In a few cases the heat of formation can be determined and electrical methods by which the potential of binary alloys is compared with that of the more positive metal in the alloy may yield important evidence as to the solubility of one metal in another in the solid state. The microscopic evidence and that of the freezing-point curves require some amplification, for they are not wholly satisfactory in this regard. (See Herschkowitz, *Zeitschrift fuer Physikalische Chemie,* Vol. XXVII., p. 113, and Laurie, *Transactions of the Chemical Society* (1888), p. 104.) One great difficulty in studying intermetallic compounds by chemical means is that even if definite crystals can be isolated from an alloy by using suitable solvents it is found that their compositions vary according to the percentage composition of the alloy from which they were obtained. Apparently identical crystals isolated from alloys of different composition, though of the same crystalline form, will usually differ on analysis. In other words, crystals need not be composed solely of a definite intermetallic compound. This seems to have been the general idea, however, in times past and every worker who succeeded in isolating definite crystals from an alloy promptly assigned to them a formula. Unless a compound is indicated by the appearance of a summit in the freezing-point curve, and unless the alloy corresponds in percentage composition exactly to this summit, it is more than likely that the crystals isolated, though

isomorphous with those of the compound, are not of exactly the same composition. This, in general, no doubt accounts for the "discoveries" from time to time of possibly ten Al-Cu compounds and nearly as many Al-Mo compounds of the types Rx-R'y, where x and y may be any number from one to twenty. To the same category belong the numerous carbides of iron. I have discovered six in the literature,—but not in iron,—the existence of all but one of which is denied. For this very reason, namely, the improbable existence of most of the intermetallic compounds mentioned in technical literature of the past ten years, I hesitate to give the formula, WAl_7, to some beautiful hexagonal crystals, which are so refractory that neither aqua regia, nor aqua regia and sulphuric acid, nor fused sodium carbonate scarcely attacks them, and whose composition agrees very closely with that formula.[10]

Cooling Curves.—During the cooling of a molten alloy, various constituents may crystallize out successively; definite compounds which are stable only at high temperatures may split up into simple constituents; or, new combinations, impossible at high temperatures, may be formed as the temperature falls. All such molecular changes are accompanied by corresponding thermal effects, such as the disengagement or the absorption of heat. By the accurate measurement of the temperature at which these changes take place we obtain most valuable information in regard to the molecular movements in the mass. The Le Chatelier pyrometer used in conjunction with an auto-photographic recording device seems best suited to measure and record these changes. The general principles of thermo-electric pyrometry are too well known to require discussion here. For reference, however, I could not do better than to refer to H. Le Chatelier and O. Boudouard's volume, *Mesure des Températures Elevées,* or to its English translation with supplement by George K. Burgess.

The instruments used by Sir William Roberts-Austen in his private laboratory have been described fully in the *Reports of the Alloys Research Committee* of the Institution of Mechanical Engineers. During several months that it was my privilege to work in his laboratory I made use of a recorder designed by Dr. Stansfield and constructed by the Cambridge Instrument Company. For a description of this, see the *Journal of the Franklin Institute,* January and February, 1902. Neither of these forms of recorder is perfect, and many improvements will be required to produce an instrument that is entirely satisfactory. Fortunately it is not the accuracy of these instruments, but certain inconveniences of manipulation that are at fault. In using any thermo-couple, with or without a recorder, it is necessary to calibrate frequently. The temperatures usually taken as "fixed points" are the boiling points of water (100°), naphthaline (218°), and sulphur (444·5°); the melting points of tin (232°), lead (329°), aluminum (655°), gold (1,064°), and copper (1,083°). Not all of these need be determined for a single calibration; three or four points if determined with great accuracy will suffice. Other points may be determined by way of verification, and it is convenient as well to have a large variety of materials to select from so that for any special work the curve may be calibrated by means of substances whose melting or boiling points lie near the temperatures at which

[10] *Journal of the American Chemical Society,* March, 1902.

we desire to operate. For instance, one would not ordinarily use the temperatures 100°, 218° and 232° in constructing a curve for use above 1,000°, but would choose 655°, 1,064° and 1,083°, or other temperatures in this region which are well established as the melting-point of potassium sulphate (1,084°), or sodium carbonate (850°).

In using the thermo-couple to obtain a cooling-curve of a metal or alloy it is only necessary to insert the couple, suitably protected by a fire-clay or porcelain tube, into the molten mass. A current of electricity is generated whose electromotive force is approximately proportional to the temperature, or rather the current gives us a measure of the difference in temperature between the hot and cold junctions of the couple. If now this current be passed through a reflecting galvanometer, the beam of light moves rapidly from left to right until it attains a deflection proportional to the temperature measured. This beam of light falls

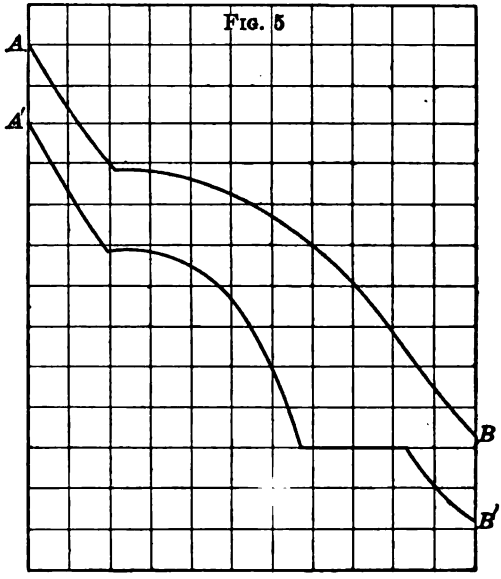


FIG. 5

upon the scale which has been calibrated by the establishment of certain fixed points as just explained. If the beam passes through a narrow horizontal slit in a recording device, behind which a photographic plate is rising or falling at a uniform rate, we obtain a cooling-curve whose co-ordinates are time and temperature. The type of curves given by a pure metal, by surfusion and impure metals has already been shown in Fig. 2. Two other classes of alloys give a cooling-curve identical with that of a pure metal, *viz.*: eutectic alloys and intermetallic compounds, that is these three classes of substances freeze at a single temperature. The nature of a eutectic will be discussed later; suffice it here to define it as that alloy of a series which has the lowest freezing-point, which is constant in composition, and which is not a chemical compound of the metals which compose it. In Fig. 5, the curve *A B* represents that of a homogeneous solid solution. It shows but one "break," though the temperature does not remain constant during the whole period of solidification, as in the case of pure metals, compounds and

eutectics. In A' B' is shown a curve with two "breaks," the upper one resembling that of a solid solution and the lower one shows the form of a eutectic. The first abrupt change in direction in either of these curves indicates the temperature at which solidification begins. As the excess of one metal solidifies the concentration of the residual fluid is increased with respect to the metal which is not in excess. The ultimate cause of the change in direction is the liberation of the latent heat of solution or of fusion.

As is well known, when concentrated hydrochloric acid (solution of hydrochloric acid gas in water) is boiled, the hydrochloric acid gas evaporates faster than the water. If dilute hydrochloric acid is boiled, the water evaporates relatively faster than the gas. The inevitable result is that at a certain concentration hydrochloric acid and water vapor leave the liquid at a rate proportional to their concentration; thereafter the composition of the liquid remains constant and the boiling point fixed.

A somewhat analogous condition is that of the solidification of two metals, M and N. Either of them may be considered as the solvent. If M is the solvent and N the dissolved substance, then on cooling such alloy, M crystallizes first retaining some N in solid solution. Similarly an alloy containing much N and little M begins to solidify by the separation of crystals of nearly pure N containing M in solid solution. As M or N begin to separate out in solid form the remaining liquid portions become concentrated in respect to N and M respectively. The freezing-point of the remaining liquid is thus continually lowered. Eventually either of these classes of alloys reaches a concentration greater than that of a saturated solid solution and then there crystallizes out simultaneously two solid solutions, one of which is a saturated solid solution of M in N and the other a saturated solid solution of N in M. In any one series of metals this takes place at a definite fixed temperature which is the lowest freezing-point in the series and no matter what the original composition of the alloy, the part solidifying at this constant temperature is uniform in composition. This is the "eutectic" alloy; it will be considered more fully later in this paper.

Some students of alloys consider that at temperatures between the first separation of solid and the point at which the residue solidifies as a whole, there does not exist a homogeneous condition in the still liquid portions. They liken alloys within this range to an emulsion, or conjugate solutions, etc., simply because ultimately the mass solidifies in a banded or laminated mass characteristic of eutectics. It is not necessary, however, to consider that the two solid solutions constituting the ordinary eutectic existed as such in an emulsified state above the eutectic point. To be sure, the microscope reveals a very marked separation of the alloy into two constituents (when there is any eutectic), usually with characteristically laminated structure, but these two components show no tendency to separate into layers when the alloy is kept for a long time just above its eutectic point; on the other hand, the magnitude of the eutectic structure is markedly influenced by the slowness of cooling. Furthermore there is always an evolution of heat during the freezing of a eutectic which is very decided and may well be accounted for by such a marked molecular rearrangement as the formation of a laminated structure from a homogeneous mass would involve, and lastly, we

might cite some concrete evidence on this point which was brought to my attention by Mr. William Campbell. As is well known the constituent of steel known as martensite which is a solid solution of iron carbide in iron is capable of splitting up at about 690°C. or nearly 800°C. below its freezing-point into the beautifully characteristic structure known as pearlite; accompanying this change is a marked evolution of heat, the critical point Ar1 of Osmond. If such a decided transformation can take place in solid steel, it surely ought not to be thought improbable that a similar one could take place in an alloy at the instant of final solidification when the molecular freedom of the particles is doubtless many times as great as in the example cited.

A cooling curve often shows more critical points or "breaks" than simply the upper one indicating the initial freezing-point and the one indicating the freezing-point of the eutectic alloy. Such subsidiary "breaks" are due to molecular changes in the solid substance and must often be considered as truly allotropic.[11] The purest electro-deposited iron shows at least five breaks in its cooling curve below the initial freezing-point. Of course there is no eutectic, and so a cause must be sought for the other five critical points. The lower two seem to be due to occluded hydrogen, while the two occurring at about 766° and 890° probably indicate allotropic transformations in the pure iron. It is now quite generally agreed that such allotropy exists, and the three varieties are designated as alpha, beta, and gamma iron. Metals and alloys which exhibited such critical points in their cooling curves will probably show corresponding critical points in their thermo-electric or electrical conductivity curves.[12] It has been objected that a slight change in the direction of a cooling curve is not sufficient evidence upon which to base an assumption of allotropy. Perhaps this is a just criticism, but if, having found such a critical point in the cooling curve, we further show that the material under investigation exhibits a sudden change in thermo-electric capacity at exactly that same temperature, and if we find that its electrical conductivity suddenly changes at that identical point we have considerable evidence that above that critical point we are virtually dealing with a new substance. If one is still skeptical as to the meaning of this point, the microscopic examination of the substance quenched from various temperatures above and below the critical point, will usually remove the doubt.

Molecular Depression of the Freezing-Point of Metals.—In 1889, Prof. Ramsey[13] determined the molecular weight of many of the metals by the method of measuring the change in vapor pressure when certain known weights of solid metals were dissolved in mercury. He also made determinations at the boiling-point of mercury. From these experiments he states "that it would appear legitimate to infer that in solution, as a rule, the atom of a metal is identical with its molecule."

Messrs. Heycock and Neville found that when two metals were melted together, considering M as solvent and N as the dissolved metal, then

(1) The freezing-point of M is lowered,—the most frequent result.

[11] Stansfield, Fifth Report, Alloys Research Committee of the Institution of Mechanical Engineers, 1899.

[12] Le Chatelier, "Sur la Résistance Electrique des Alliages," in *Contribution a l'Etude des Alliages*, Paris, 1901.

[13] *Transactions of the Chemical Society*, 1889. (55), p. 521.

(2) The freezing-point of M is raised, *e.g.*, silver in cadmium, and antimony in tin.

(3) The freezing-point is unchanged, *e.g.*, thalium in lead, and, I believe, within narrow limits, silver in gold.

But these skillful investigators, to whom we are so much indebted for their careful researches upon alloys, went further and showed that none of these cases contradicted Van't Hoff's theory of solution. This they did in each case by filtering off the part first solidifying. In the first case the more fusible filtrate was found to be richer in the dissolved metal than were the first crystals. In the second instance the crystals were richer in the dissolved metal; that is, the excess of solvent was not first to separate in the solid form but what was probably a definite compound of the two metals having a higher melting point than the metal M, which was assumed to be the solvent. In the third case there was absolutely no separation of the two metals during cooling; that is, the first crystals and the fluid part were identical in composition. That is, the two metals in these instances form isomorphous mixtures. In all their experiments, Messrs. Heycock and Neville were dealing with dilute solutions in which, as in the case of salts dissolved in water, it might be expected that the molecules of the dissolved substance would obey the laws of gases. When their experiments were conducted quantitatively, Heycock and Neville[14] found that two of the empirical laws of Coppet and Raoult hold good for alloys, *viz.*:—

(1) For moderate concentration the fall of freezing-point is proportional to the weight of dissolved substance present in a constant weight of solvent, and

(2) When the falls produced in the same solvent by different metals are compared, it is found that a molecular weight of a dissolved metal produces the same fall whatever the metal is.

In these experiments tin was the solvent, and it was assumed that the metals are monatomic in solution or that their molecules are of one type,—Rn when n is constant and probably equal to 1.

The third law is probably incorrect, for it assumes that if a constant number of molecules of solvent be employed, the fall is independent of the nature of the solvent. The solvent in the case of metals often tends to chemical combination with the other metal. Thus, gold in 100 atoms of sodium gave 4°C. depression in the freezing-point; in tin, 3°C. and in potassium only 1·8°C.

Freezing-Point Curves.—One must not confuse cooling-curves and freezing-point curves. The former, as already pointed out, result during the cooling of a single metal or alloy and time and temperature are the co-ordinates of such curves. When a series of such curves are obtained for any pair of metals mixed in all proportions from 0 to 100% M in 100 to 0% N, and the critical points are plotted in a diagram of which the co-ordinates are temperature and composition we get what is known as a freezing-point curve. That is, the points at which all possible combinations of the two metals freeze are indicated more or less accurately. The more points in the curve actually determined, the more likely becomes the accuracy of the other points. Subsidiary points in the cooling-curves may also be plotted, though they are not strictly speaking freezing-points. Fig. 6

[14] Heycock and Neville, *Transactions of the Chemical Society*, 1890 (57), p. 376

is taken from a paper upon "La Constitution des Alliages Metalliques," by Robert-Austen and Stansfield, which was presented at the Physical Congress, Paris, 1900. The vertical co-ordinate is temperature and the horizontal one represents both time (for cooling-curves) and composition (for the freezing-point curve). It shows graphically how a complete freezing-point curve is constructed from cooling-curves. It will be noticed that the metals *A* and *B* forming the alloy give

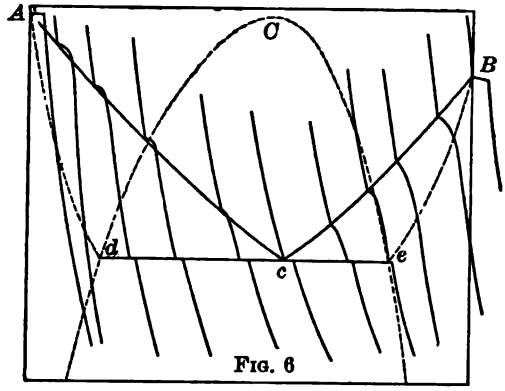


FIG. 6

cooling-curves of the type of pure metals. In the curves showing a eutectic break, it will be noticed that the magnitude of the eutectic break as compared with the upper or freezing-point break becomes relatively greater as we approach the composition of the alloy *c* which is pure eutectic and gives a cooling-curve identical in form with those of *A* and *B*. In fact this ratio gives a rough approximation of the proportion of the alloy which consists of solid solution separating at the

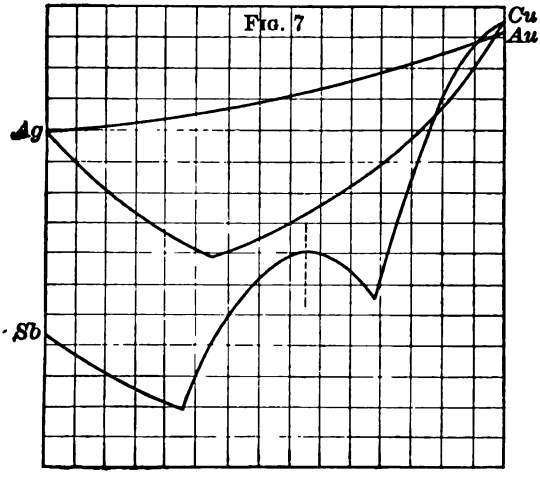


FIG. 7

first break and eutectic alloy crystallizing at the fixed temperature indicated by the horizontal part of the cooling-curve; or, in other words, if the alloy consists mostly of solid solution and a little eutectic, it will take the former longer to solidify than it does the latter and the cooling-curve indicates this roughly.

Freezing-point curves conform in general to three types, as shown in Fig. 7. These curves are not drawn exactly to scale, but are approximately correct. Gold and silver alloys form perfectly isomorphous mixtures, and their freezing-points give almost a straight line joining the freezing-points of the pure metals. Copper and silver give the typical curve of two metals, which mix in all proportions, but do not unite chemically. Antimony and copper unite to give the highly-colored compound known as regulus of Venus, Cu_2Sb.[15] This compound is indicated in the cooling-curve by the intermediate summit. In general such a summit will be found to occur at a formula percentage, and indicates an intermetallic compound. To explain such a curve, we have only to consider it as made up of separate sections, as indicated in the figure by a dotted line. The intermetallic compound has a melting-point of its own, quite independent of that of the constituent metals. It may be higher, lower or intermediate as compared with the constituent metals which compose it. In such a curve as the *Sb-Cu* one, we may consider that one series of alloys is composed of mixtures of Sb and $SbCu_2$, and the other of $SbCu_2$ and Cu. We are virtually dealing with two distinct series of alloys, each of which taken separately is of the simple type illustrated by the

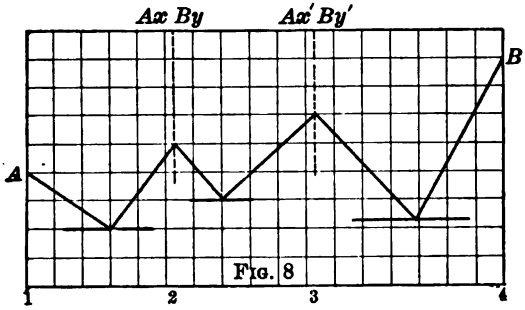


FIG. 8

Ag-Cu curve. In the Sb-$SbCu_2$ portion of the curve there is no free copper, and in the Cu-$SbCu_2$ portion of the curve there is no free antimony. Dissociation of the compound might make some modification of the above statement necessary, and, indeed, it has been suggested that dissociation causes a summit to appear rounded instead of angular. Curves containing more than one summit may be similarly resolved into series of two components, which may be respectively a metal and an intermetallic compound, or, if between two summits, the components are both intermetallic compounds. An ideal representation of such a curve is shown in Fig. 8. In this figure we see that alloys whose compositions fall between 1 and 2 consist of metal *A* and compound *Ax By;* alloys between 2 and 3 consist of components *Ax By,* and *Ax' By'*—they contain no free *A* or *B;* alloys between 3 and 4 consist of compound *Ax' By'* and metal *B*. Each of these pairs of components has its melting-point depressed by the presence in it of the adjacent component. Our *Cu-Al* curve (Fig. 9) may be explained in this way: Two summits occur at the compositions corresponding to Cu_2Al_3 and $AlCu_3$ (48·49% Cu, and 87·6% Cu respectively). Le Chatelier thinks he has detected with the microscope at least four compounds. Our curve gives no indication of them. Our own micro-

[15] The formula usually given in the past was Cu_3Sb_2, but Stead says the purple constituent is Cu_2Sb.

scopic study of these alloys is not yet completed.[16] Our *Al-Sb* curve (Fig. 9) shows the presence of a compound whose melting-point is more than 400°C. above that of either constituent. Its formula is SbAl (81·6% Sb). In this series of alloys we are dealing with two pairs of constituents, Al-AlSb and AlSb-Sb. The compound seems to be almost insoluble in either of the pure metals, but on theoretical grounds we should expect to find a slight depression in the freezing-point of each metal as indicated in the curve. These points have not as yet been experimentally

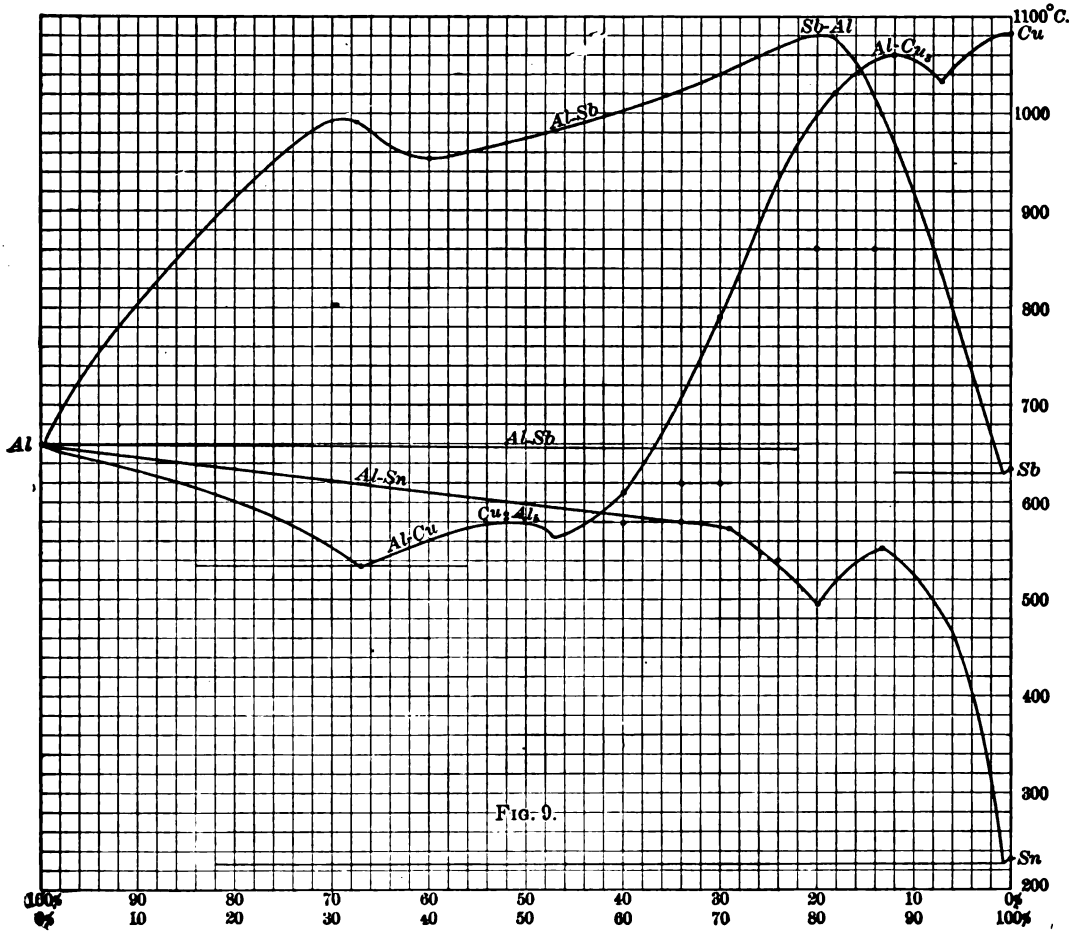


FIG. 9.

detected. The tin-aluminum curve shows a fall of 3° or 4°C. by the addition of 0·5% Al, while with increased additions of aluminum the freezing-point is raised 300°C. at a concentration of 10% Al, 90% Sn.

If in a certain series of alloys we get a freezing-curve with a summit occurring at a formula percentage, and examine the alloys whose freezing-points give rise to that summit, we shall find that in general an intermetallic compound in the

[16] Recent work by Mr. Campbell, soon to be published, shows the *AlCu* series to be quite as complicated as the *CuSn* series, so skillfully worked out by him. (*Proceedings of the Institution of Mechanical Engineers*, 1901.)

pure state presents under the microscope a homogeneous mass made up of crystals, all of which are the same. As we descend from the summit on either branch of the curve we find these crystals becoming less and less in number and size, and at the next angle in the curve they disappear entirely. This is illustrated by the accompanying photographs of antimony-aluminum alloys. These micro-photographs were made by Mr. Campbell.

Fig. 10.—20% Sb, 80% Al ×33 diameters, oblique illumination, shows crystals of SbAl in granular ground mass of nearly pure Al.

Fig. 11.—50% Sb, 50% Al ×33 diameters, oblique. Crystals of SbAl increasing in size and amount, ground mass decreasing.

Fig. 12.—82% Sb, 18% Al ×16 diameters, vertical illumination. This photograph shows nearly pure SbAl.

Fig. 13.—85% Sb, 15% Al ×33 diameters, vertical illumination. We have passed the summit of the curve; the ground mass of aluminum has disappeared and some free antimony is seen.

Fig. 14.—95% Sb, 5% Al ×33 diameters, oblique. SbAl crystals diminishing in quantity, and ground mass of Sb—probably containing a little SbAl in solid solution—is conspicuous.

Regarding this microscopic evidence, supporting the pyrometric evidence, Mr. Neville[17] says: "These criteria taken together, (1) the occurrence of a summit at a formula percentage, (2) the presence of large crystals of the same kind, decreasing in amount as we descend the branch on either side, are an absolute proof of the reality of a compound."

The Nature of Eutectics.—In several portions of this paper eutectic alloys have been mentioned, a term for which we are indebted to Dr. Guthrie, who used it to designate the most fusible alloy of a series—the one which freezes last. There are certain points in which eutectics may differ, and upon these differences they may admit of classification. Every eutectic, however, possesses the following properties:—

1. It is of uniform composition in any one series of alloys.
2. Its freezing-point is constant throughout any one series.
3. The freezing-point is the lowest in the series.
4. It is not a chemical compound.

The composition of a eutectic may and occasionally does correspond to some simple atomic ratio. This coincidence, though striking, does not prove the presence of a compound as the sole constituent of a eutectic. Usually it possesses a laminated micro-structure, and often requires very high magnification to detect the two constituents. Mr. Stead, in his splendid paper upon iron and phosphorus, gives his ideas upon the subject of eutectics, and in addition to what has just been said as to the essentials of a eutectic, he adds some remarks upon what a eutectic may be: (1) "It may consist of two or more metals which do not unite chemically, or (2) of a metal and a definite compound (containing that metal), or (3) possibly of two or more definite compounds. (4) It may consist of a mixture of a solid solution of one metal in another and a free metal. (5) It may contain a solid solution of a definite metallo-metallic salt (intermetallic com-

[17] *British Association Report* (1900), "Upon the Chemical Compounds Contained in Alloys."

pound) and that same metallo-metallic salt in the free state. (6) It may possibly consist of two solid solutions." The last of these statements, which he qualified by the word "possibly," seems to me to be the most important of all; and since I am unwilling to admit that any metal or intermetallic compound ever separates absolutely pure, those conditions in which Mr. Stead speaks of the separation of pure substances seem to me to be inaccurate. The form of the freezing-point curves and the explanation of them according to Prof. Roozeboom renders it highly improbable that any strictly pure material separates at the freezing-point of the eutectic. The most that we can say of the constituents of a eutectic is that in certain cases they are solutions of extreme dilution. In cases where the freezing-point curve lies almost entirely above the melting-point of either or both constituents, but in which there is a slight depression of the freezing-point by very small additions of one metal to the other, as in the case of tin-aluminum, previously mentioned, and when this depression is further indicated in a well-marked eutectic break in other alloys of the series, it may be possible that the eutectic is a single solid solution. The quantity of dissolved metal in such a eutectic might not be enough to change the type of cooling curve seriously, and probably exceedingly high magnification would fail to resolve such an eutectic into two components, for it crystallizes isomorphously with the pure tin, hence it seems that no two juxtaposited constituents are there. This conception of a eutectic is not at variance with the four essentials already enumerated. While not speaking positively on this point, I think it reasonable, and am not sure but that in such a curve as the Sb-Sn curve, where all the points seem to lie above the melting-point of tin, we must consider pure tin as the eutectic—it melts lowest for the series, it is of constant composition, and it is not a chemical compound.

We have now indicated many points of resemblance between metallic mixtures and ordinary solutions. One metal diffuses into another like a salt into water; like two liquids, they may be perfectly miscible or form layers; the layers are not pure, but each contains a little of the other in solution; in general, the solubility increases with the temperatures. They will flow under pressure; they may or they may not react chemically when brought into intimate association by fusion or pressure; the molecular mobility increases with the temperature; upon cooling of binary alloys we observe phenomena strongly suggestive of the freezing of salt solutions; the depression of the freezing-point of one metal when another is added follows the laws of Coppet and Raoult, and the eutectic reminds us very much of the "cryohydrates" of ordinary solutions. Scarcely another point of resemblance is needed, but one is at hand, and a very important one, *viz.*, the phase rule applies quite as well to the explanation of conditions of equilibrium in alloys as it does to the explanation of similar problems in regard to liquid solutions. The classification of the systems, however, requires some modification before the generalizations of Trevor apply, and it is practically somewhat difficult to ensure complete equilibrium in an alloy—the cooling is usually much too rapid to allow of the establishment of equilibrium in the solid mass. If equilibrium has been established, then the number of distinct substances in the mass will depend upon the number of constituents which enter into the composition of the mass. In my

paper already referred to in the *Journal of the Franklin Institute,* February, 1902, I have shown how the adaptation of the phase rule to alloys is accomplished, and as this is more a chemical conception than one of direct interest to engineers, it need not be dwelt upon here. The phase rule does not tell us the number of phases in which one or two components may exist, but how many of them may exist simultaneously in equilibrium. Thus pure iron may exist in three solid, and one liquid phase, but never in all four at one time. Again the iron-carbon alloys, according to Roozeboom, may exhibit at least seven phases, *viz.,* carbon, alpha-, beta- and gamma-iron, liquid solution, solid solution of carbon in gamma-iron, and cementite or iron-carbide. The provisions of the phase rule, however, tell us that only three of these may exist in equilibrium at any given temperature and concentration. Prof. Roozeboom's explanation of a freezing-point curve considered as an equilibrium curve is of great interest in helping to make clear the series of phenomena which are exhibited during the actual solidification of molten alloys. His original explanation was given in connection with the highly complicated iron-carbon curves of Roberts-Austen. It has seemed to me that a simpler figure would lend itself more readily to this explanation and the accompanying figure shows the type of curves which gold-copper and copper-silver alloys give, *i.e.,* pairs of metals soluble in each other in all proportions but not forming any compounds. In Fig. 15 the curve *a e c* represents the temperatures at which for each concentration solidification begins. The curve *a b d c* shows the temperature at which solidification is complete. Except for the straight portion of this curve, *b d,* the exact position of it is a matter of conjecture. According to Stansfield, its position may be calculated with some degree of accuracy upon theoretical grounds, if the latent heat of fusion of the solvent is known and assuming that the dissolved substance is monatomic in the liquid state. The upper line, *a e c* Roozeboom calls the "liquid" curve, and the lower line, *a b e d c* he calls the "solid" curve. When in a series of alloys the liquid and solid curves have a maximum or minimum point formed by the branches of the curve, they touch at this point as in the curve before us. The point in our diagram where the liquid and solid curves meet is the eutectic point. It means that the liquid represented by the composition corresponding to that point solidifies as a whole at a single temperature. Curves similar to this may be used to explain such complicated freezing-point curves as that of the Al-Cu series, remembering that

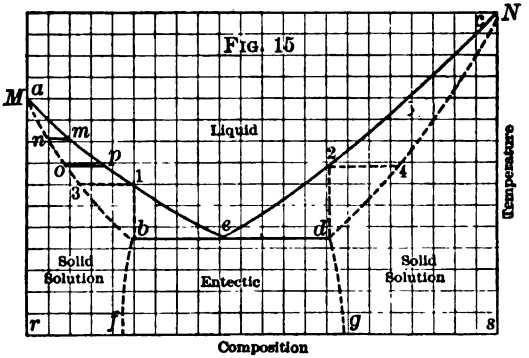


FIG. 15

the terminii of the liquid and solid curves are not necessarily pure metals, but may be a metal and a compound, or perhaps two compounds. The more or less triangular areas, *a b e* and *c d e* represent mixtures of liquid and solid phases. The areas *a b r f* and *c d g s* are solid solutions, and in the area *b d f g* we have a conglomerate of eutectic alloy, with varying amounts of crystals of solid solution depending upon the composition of the alloy from which they were derived. At the single composition *e*, however, we have an exception to this statement, for this alloy consists of eutectic only, while to the left of this the conglomerate consists of eutectic plus solid solutions of N in M, and in alloys represented by compositions to the right of *e* we have eutectic (always constant in composition) plus more or less of a solid solution of M in N.

Above the liquid curve we have only liquid phases; below the solid curve we have only solid phases, while intermediate areas correspond to a mixture of liquid and solid phases.

Any alloy whose composition falls within the areas marked solid solution gives but one break in the cooling curve. Alloys represented by compositions falling within the area of the eutectic (except alloy *e*) give two breaks in the cooling-curves. The eutectic itself consists of two solid solutions, whose compositions are indicated by compositions corresponding to the extreme ends of the eutectic line, *viz.*, *b* and *d*. However, since the solubility of one metal in another is a function of the temperature below its freezing-point as well as above, we may assume that the solubility in the two components of the eutectic decreases slightly even after solidification, and therefore the lines *b f* and *d g* are represented as slanting rather than perpendicular to the composition line. These lines indicate the maximum solubility of either metal in the other at temperatures below the freezing-point of the eutectic.

Let us consider the phenomena of solidification of an alloy represented by a composition on *a e*, as explained by Roozeboom. Any solution represented by the composition *m* begins to solidify at that temperature by the separation of crystals of the composition *n*. They therefore contain less of N than the liquid alloy *m*. The residual alloy has therefore become enriched in N, and its freezing point is lowered; its composition passes thus from *m* to *p*, at which point solidification is complete, for at this point the temperature has fallen till it encounters the solid curve at the point *o*. The point *o*, moreover, indicates the composition of the last crystals to solidify. That is, while the liquid solution is changing from *m* to *p*, the composition of the crystals has changed from *n* to *o*. Complete solidification has thus taken place through an interval, *m o*. Now there is an alloy whose final solidifying point is *b;* and according to Roozeboom's explanation it is an alloy of composition, *e*, which is freezing. At the same temperature, however, occurs the solidification of the solid solution of composition *d*. Finally, then, all alloys represented by compositions between 1 and 2, after separating out crystals of solid solutions of N in M, or M in N, represented by compositions along the lines 3, 1 and 2, 4, respectively, become concentrated to the composition *e*, where saturated solid solutions of compositions *b* and *d* solidify side by side, constituting the eutectic. That is, an alloy the vertical projection of whose composition upon the solid curve does not cut the eutectic line, consists of a single solid solution. An alloy whose

composition projected vertically intersects the eutectic line, consists of a conglomerate of eutectic of constant composition *e* and a solid solution, whose composition is represented by the horizontal projection of its composition upon the corresponding solid curve. At temperatures and concentrations lying within the areas enclosed by the liquid and solid curves there exists in equilibrium solid and liquid solutions, *e.g.*, at a temperature and concentration represented on the line *m n* there exists simultaneously liquid solution *m* and solid solution *n*.

Great as has been the progress in alloys research within the past few years, yet much remains to be done. When many sets of complete freezing-point curves have been determined, when all the alloys of these series have been examined metallographically, and when their ordinary physical tests, tensile strength, electrical and heat conductivity, specific gravities, etc., have been accurately worked out, then we may be able to generalize and to predict properties of new pairs of metals as well as to set out intelligently to produce new and useful alloys. It must be admitted that the production of alloys in the past has been by the very wasteful method of chance. I hope to see the manufacture of alloys become an exact science and that ultimately even ternary or more complex alloys may be brought within the range of applicability of "natural laws," which as yet remain undiscovered. We are making progress in the right direction, but American scientists have not yet assumed their due share of this task. It is time that we followed the example of the British Association, the Société d'Encouragement pour l'Industrie Nationale, the Institution of Mechanical Engineers and the National Physical Laboratory of Great Britain, in promoting the scientific study of problems in connection with alloys.

REVIEW OF THE LITERATURE ON ORE DRESSING IN 1901.

By R. H. Richards.

Crushing Machinery.

Hall's Multiple Action Ore Crusher.[1]—This breaker is practically a duplex Blake, the moving jaw being divided vertically into two parts so that when one half is working forward, the other is returning, which ensures more uniform and continuous running, and equalizes the strains; furthermore, the required maximum effort is only one-half as great as that of an ordinary Blake breaker of equal capacity, the former crushing all the time and the latter only one-half of the time.

Huntington Mills.[2]—At the Butte and Boston mill, Butte, Mont., these mills crush coarse jig-tailings having an average size of 0·25 in. to 20 mesh. The capacity of each mill is 75 tons per day.

Chilled Steel Roll Shells.[3]—At a mill in Lauthenthal experiments are in progress with chilled steel and cast steel shells; a partial report is as follows:—

Shell.	Working Time.	Ore Crushed.	Wear.	Price per Pair.
	1901.	Cu.m.	Mm.	
Chilled Steel....	June 23 to Nov. 20.	2,639	24	$92·56
Cast Steel.....	July 6 to Nov. 20.	1,959	29	57·12

In view of the longer life of the chilled steel shells and the consequent decreased running cost, it is probable that they will be substituted for the cast steel shells. A calculation based on a comparison of the wear per ton of ore crushed and the respective costs of the shells show a difference of about half a per cent. in favor of chilled steel.

Classifiers.

The Klein Classifier operates as follows: As the ore mixed with water comes from the trommels it passes into a receiving chamber from which it flows into a slightly tapered box-shaped compartment, where the classification takes place. This compartment is about 24 in. long at the base, 9 in. wide, and 9 in. deep.

[1] *Feilden's Magazine*, 1900, Vol. III., p. 539. [2] *Ibid.*, 1901, Vol. IV., p. 243.
[3] *Zeitschrift fuer das Berg-, Huetten-, und Salinenwesen*, 1901, Vol. XLIX., p. 332.

Air at about 25 lb. pressure is admitted through six holes 0·375-in. diameter in the base and on the sides through hoods with sprays of perforated copper. Hydraulic water is introduced by two 1·25-in. pipes. The outlet pipe is on a line with the hydraulic pipe, and is 2 in. above the base of the box. The air as it comes from the bottom of the classifier carries to the top a certain amount of fine material while the larger particles remain behind and are washed out.[4]

Dimmick Classifiers are in use at the Helen Mining Co., near Cooney, New Mexico.[5] This apparatus consists of a V-tank 15 ft. long by 10 ft. high. It has a main central partition with intermediate small partitions. The action is simply that of a distributor, the pulp going to vanners and slime tables.

JIGS.

The New Century Drop Motion Jig.—This jig does not use eccentrics; it lifts the plunger rod by a cam having a maximum lift of from 1 to 1·5 in., thereby compressing a spring which on the release imparts a quick down thrust. It is adjustable, and hence when working with usual stroke of 0·125 to 0·375 in., it affords the plunger a period of absolute rest; it is also claimed to use less power than with an eccentric jig. This jig is fully described and illustrated by Frank Nicholson in his article on "Mining and Milling in the Joplin District, Missouri," elsewhere in this volume.

The Klein Jig[6] is being used in southeast Missouri and in the Philipsburg district of Montana. It very closely resembles the Hartz jig in general form, but instead of driving each plunger by an eccentric, two jigs are mounted side by side and their plungers are driven from opposite ends of rocking arms, mounted on a longitudinal rocker-shaft which is rocked through a crank, connecting rod and eccentric. The discharge of concentrates above the sieve is aided by a puff of compressed air at every downward stroke of the plunger. This is under from 25 to 30 lb. pressure. The advantages claimed are: (1) less power required, as any number of plungers may be operated by one eccentric; (2) greater capacity; (3) cleaner separation.

FINE CONCENTRATORS.

The Dimmick Concentrator[7] consists of a stationary rectangular plane table covered with canvas and thickly studded with nails, which act as riffles; the slope of the table depends upon the coarseness of the material to be treated and the action is intermittent.

The New Standard Concentrators[8] are used at the Last Chance mill, three of these concentrators treating from 15 to 20 tons of ore per table per day, the ratio of concentration being 100 to 1. The tables are of the bump type suspended from three points, and are easily adjusted to wide variations in slope. The strike is usually 0·75 in. and about 225 per minute. The floor space is 11×15 ft. The table is covered with linoleum, and has a water consumption of 3·5 gal. per minute.

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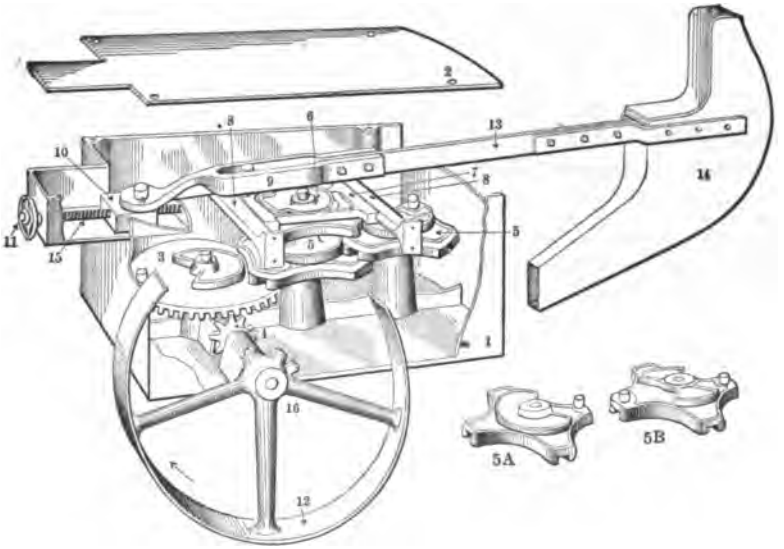
[4] *Transactions of the American Institute of Mining Engineers*, 1901, Vol. XXX.
[5] *Mines and Minerals*, 1901, Vol. XXII., p. 98.
[6] *Transactions of the American Institute of Mining Engineers*, 1901, Vol. XXX.
[7] *Mines and Minerals*, 1901, Vol. XXII., p. 98. [8] *Ibid.*, p. 99.

The Overstrom Table which appeared in 1901 is the latest form of riffle table. Its shape is that of a rhomboid. The line of the riffle blocks and the direction of motion of the table are the same and are nearly parallel to the shorter diagonal of the rhomboid. This table closely resembles the Wilfley, the principal difference being in a diminution of the idle spaces and in addition to the working spaces.

The Wilfley Table.—In a suit brought by A. R. Wilfley against the Denver Engineering Works, a decision was rendered in complainant's favor, the court stating: "It may be that the Cammett tables are an improvement upon the invention covered by the Wilfley patent in this respect (directing and delivering concentrates), but it still has all the essential elements of the best form of Wilfley's invention; it performs the same function in substantially the same way, and therefore must be held to infringe it."

Accessory Apparatus.

The Scobey Sampler is a device for sampling material which is transported by water. As shown in Fig. 1, it consists of a belt-driven mechanism which passes



1 Case	5 Intermittent Gear	8 Guide	12 Pulley
2 Cover	5A Single	9 Arm	13 Extension Arm
3 Bevel Gear	5B Double	10 Sliding Center	14 Bucket
4 Driving Gear	6 Mutilated Gear	11 Hand Wheel	15 Adjusting Bolt
	7 Yoke		16 Shaft

Fig. 1.—The Scobie Sampler.

a bucket through a falling stream of pulp and water, deflecting only a very small portion to a convenient receptacle. When not taking samples the bucket is automatically locked; it can be adjusted to take from 0·01 to 0·0001 part of whole. The list price of this sampler is $36 and during the past year it has been endorsed by several prominent milling engineers.

This sampler conforms to the essential rule of taking the whole of the stream part of the time.

The Geissler Sampler.—There is nothing new to be added to the description of this sampler already given by Prof. H. O. Hofman in THE MINERAL INDUSTRY, 1900, Vol. IX., p. 440.

An Automatic Sampler[9] at the Smuggler mills, Aspen, Colo. (which is illustrated in the reference given), consists of a scoop for taking or deflecting a portion of the whole stream of tailings and is suspended from a tipple tank. Water is supplied through a pipe to the high side of the tipple which on filling falls, causing the scoop to pass through the stream. On reaching the lowest portion of its movement a valve is opened by impact allowing the water to discharge into the waste tank. A retarding device is attached to the tipple to prevent too easy movement, making it necessary for the tipple tank to be nearly filled before the movement commences. A pneumatic check is applied to regulate the speed and the quantity taken. The deflected sample is further reduced by a split-shovel arrangement in the sample launder.

A 12-in. Robins Belt Conveyor[10] is used at the British Columbia Copper Co.'s plant at Greenwood, B. C., to take the undersize from the grizzly to the ore bins, the oversize passing to a breaker. A 36-in. sorting conveyor, 111 ft. center to center, takes the ore from the breaker to the ore bins. The discards from picking are removed by a 12-in. and a 16-in. conveyor (540 ft. center to center). Picking is reported to cost 6c. per ton.

The Homestake Mining Co. has installed three belt conveyors,[11] each 167 ft. long, to convey ore from the shaft house to the mill. These are driven from the discharge end, require 3 H.P. each and handle 480 tons per 24 hours. The ore is fed by one boy and is sorted in transit, which by removing chips and pieces of wood increases the capacity 10 to 20 tons per day, as the stamp screens do not clog.

The Jeffrey Belt Conveyor[12] for handling wet or dry ore is now arranged so that the belt may be made concave or convex, which allows the water to drain off in the latter case.

TESTING DEVICES.

A New Laboratory Classifier[13] has been constructed by Prof. Henry S. Munroe (see Fig. 2). In the original classifier the material was fed through a stop-cock funnel, a method which seriously limited the capacity and efficiency of the apparatus. The funnel is now replaced by a second Erlenmeyer flask connected directly with the apparatus by a short length of rubber tubing of large diameter.

Laboratory Slime Table.[14]—Prof. Henry S. Munroe has also constructed an excellent rectangular slime table for laboratory use consisting of a strong metal frame about 5 ft. long in which flat plates may be secured. The means of varying the adjustments have been carefully designed and some of the usual difficulties overcome. The table is illustrated in Fig. 3.

[9] S. I. Hallett, *Mining and Scientific Press*, 1901, Vol. LXXXIII., p. 55.
[10] *Mining and Scientific Press*, 1901, Vol. LXXXIII., p. 47.
[11] *Engineering and Mining Journal*, Nov. 30, 1901, p. 722.
[12] *Mining and Scientific Press*, 1901, Vol. LXXXII., p. 342.
[13] *School of Mines Quarterly*, 1901, Vol. XXII., p. 449.
[14] *Ibid.*, p. 306.

In a Laboratory Amalgamating Device[15] vertical agitation is given to a small table working between guides on which are strapped broad mouthed bottles carrying the ore to be amalgamated. The throw is 2 in. with 350 revolutions of the eccentric per minute. Results check to within a maximum error of 2·5% of

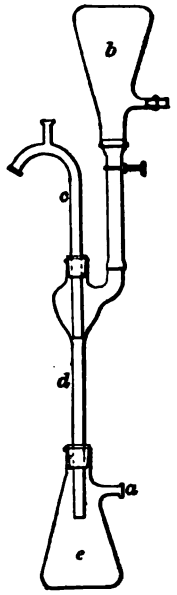
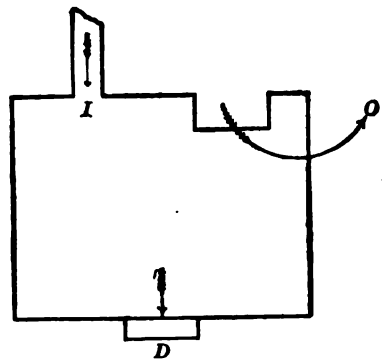


FIG. 2.—A LABORATORY CLASSIFIER.



I=Inlet. *O*=Outlet. *D*=Bottom discharge doors.

FIG. 3.—A LABORATORY SLIME TABLE.

the mill results which allows the company to buy small lots of ore and to mill them collectively instead of separately as before.

MILLS AND GENERAL MILLING CONSIDERATIONS.

The Helena-Frisco Concentrator,[16] at Gem, Idaho, treats daily about 600 tons of argentiferous galena carrying a considerable amount of blende. The following outline is given of the process of working: The ore from the mine is trammed to the mill bin (1).

(1) Mill Bin to (2).

(2) Grizzly. Oversize to (3); undersize to (4).

(3) One 10×20-in. Blake breaker set at 1 to 1·25 in., to (4).

(4) One pair No. 1 Rolls, 30×15 in. set at 0·75 in. to (5).

(5) Two No. 1 trommels, with 10 mm. and 15 mm. holes. Over 15 mm. to (6); through 15 on 10 mm. to (7); through 10 mm. to (10).

(6) Three 3-compartment Bull Jigs. Heads to (8); tailings to waste.

(7) Six 4-compartment Hartz Jigs (four of which treat material 15 mm. on 10, and two 7 mm. on 10). First and second discharges to (34); third and fourth discharge to (8); tailings to (36).

(8) No. 1 Elevator to (9).

[15] *Mining and Scientific Press*, 1901, Vol. LXXXIII., p. 130.

[16] *Journal of Canadian Mining Institute*, 1901, Vol. IV., p. 254.

(9) One pair No. 2 Rolls, 36×14 in. to (5).

(10) Two No. 2 trommels, with 3, 5, and 7 mm. holes; over 7 mm. to (7); through 7 on 5 mm. to (11); through 5 on 3 mm. to (12); through 3 mm. to (12).

(11) Two 4-compartment Hartz Jigs; first and second discharges to (34); third and fourth to (14); tailings to (36).

(12) One Calumet Classifier. First, 2d, 3d, 4th, and 5th spigots to (13); overflow to (24).

(13) Eight 4-compartment Hartz Jigs. First and 2d discharges to (34); 3d and 4th discharges to (14); tailings to (36).

(14) Settling box. Spigot to (16); overflow to (15).

(15) Long settling tank. Spigots to (16); overflow to (35).

(16) No. 2 Elevator. To (17).

(17) Two pairs No. 3 Rolls, 30×14 in. to (18).

(18) One trommel with 3-mm. holes. Oversize to (19); undersize to (21).

(19) No. 3 Elevator. To (20).

(20) One pair No. 4 Rolls 24×14 in. To (18).

(21) Two Calumet Classifiers. First and 2d spigots to (22); 3d, 4th and 5th spigots to (23); overflow to (24).

(22) Four 4-compartment Hartz Jigs. First, 2d, and 3d discharges to (34); 4th discharges to (14); no tailings made; overflow to (36).

(23) Four 4-compartment Hartz Jigs. First and 2d discharges to (34); 3d and 4th discharges to (14); no tailings made; overflow to (36).

(24) Settling tank. Spigot to (25); overflow to (28).

(25) Nine convex revolving slime tables. Heads to (34); middlings to (26); tailings to (36).

(26) No. 4 Elevator to (27).

(27) Settling tank. Spigot to (29); overflow to (30).

(28) Settling tank. Spigot to (29); overflow to (30).

(29) Ten 6-ft. Frue vanners. Heads to (34); tailings to (31).

(30) Outside settling tank. Spigot to (31); overflow to (36).

(31) Settling tank. Spigot to (32); overflow to (36).

(32) Four 6-ft. and four 4-ft. Frue vanners. Heads to (33); tailings to (36).

(33) Ore pile (finished product).

(34) Two concentrates settling boxes. Overflow to (35).

(35) Overflow settling box; settlings returned to mill; overflow to (36).

(36) Tail race to waste.

In the Galena-Joplin Lead and Zinc district[17] similar methods of milling are generally employed with the exception that classifiers are used extensively in the Joplin section, and rarely in the Galena section. The following is the general method of milling. The ore from the mine goes to (1).

(1) Grizzlies. Oversize to (2); undersize to (3).

(2) Sledge. To (3).

(3) Breaker. To (4).

(4) No. 1 Rolls. To (5).

[17] *Mines and Minerals*, 1901, Vol. XXI., p. 465.

(5) No. 1 elevator. To (6).

(6) Trommel. Oversize to (8); undersize to (7).

(7) No. 1 or roughing jig. Heads to (9); middlings to (10); tailings to waste.

(8) No. 2 Rolls to (5) and (6).

(9) No. 2 elevator. To (11).

(10) No. 3 elevator. To (12).

(11) No. 2 or cleaning jig. Heads to market; middlings to (13); tailings to waste.

(12) No. 3 rolls. To (5).

(13) No. 4 elevator. To (14).

(14) Sand jig. Heads to market; middlings to (15); tailings to waste.

(15) Slime treatment (sludge mills).

When classifiers are used they are generally attached to the rear end of the No. 2 or cleaning jig and are also arranged to receive the drain from the hutch work of the jigs. The slimes are treated at centrally located sludge mills for the production of fine concentrates.

The sludge mills work on slimes and tailings, averaging between 3% and 7% blende. The concentration is accomplished by rolls, jigs and buddles; or by Wilfley tables. The capacity in both cases is small because of the lean tailings and slimes, due to the increasing care exercised by the large mills. In the first type of sludge mill the material receives no further crushing after leaving the jigs. The heads from the cleaner and sand jigs are the only products which are directly marketable to the smelter. The middlings and slimes from the jigs go to roughing and cleaning buddles for final treatment. In the second type of mill Wilfley tables are used as roughers and cleaners, usually one cleaner to two roughers. As the sludge mills are independent of the large mills it would seem that a great saving could be made at the latter by introducing some form of slime treatment for the rich slimes from the cleaner or sand jigs before they become mixed with waste material and become worthless. A step has been taken in the right direction by the operators in the Joplin portion of the district where classifiers are employed to save jig slimes. The attempts made to use the round table have been unsuccessful.

At the Ashio Mill, Japan,[18] a separate concentration is used for each of the two classes of ore, with the exception of four products from the first class, which are run into the second. The ore consists of copper pyrites associated with iron pyrites, galena, arsenopyrite and blende; the first class ore averages from 11% to 12% Cu, and the second class about 1·5% Cu; the former is concentrated to 20% Cu, while the latter is brought up to 12% Cu; the mixed concentrates are sent to the smelter, and average 16% Cu. The arrangements of the mills are similar, consisting of rock breakers, trommels, cobbing tables, rolls, jigs and settling tanks. It is stated that from 87% to 92% of the copper content of the first class ore is saved, and from 59% to 65% ore of the second class.

The Humphreys Mill,[19] *at Creede, Colorado,* upon its completion will dress ores

[18] *Berg- und Huettenmaennische Zeitung*, 1901, Vol. LX., p. 261.

[19] *Mining and Scientific Press*, 1901, Vol. LXXXIII., p 218.

as follows: from bins to grizzly by trams; oversize going to 10×30-in. breaker, joins the undersize and goes through an automatic sampler to a roughing trommel; thence to two sets of 14×36-in. rolls; then elevated and passed through two sets of screen lines each consisting of four 3×6-ft. screens. Everything above 16-mesh is handled by 4-compartment Hartz jigs, while through 16-mesh is run to four Bartlett tables. Tailings are reground in three sets of 14×30-in. rolls, sized by revolving screens, the oversize being elevated by Frenier sand pumps; the pulp is classified in hydraulic sizers and distributed on 12 Wilfley tables. The capacity of the mill is expected to be 150 tons per day.

The Chainman Mill, at Ely, Nevada,[20] is in process of construction, and will consist of eight departments, *i.e.*, screening and crushing, amalgamating, concentrating, sizing and settling, leaching, precipitating, slimes treatment, refining and assaying. The crushing will be done by an Austin gyratory breaker followed by rolls, from which ore goes to Chile mills, thence over plates to Cammett tables, and then to settling tanks for leaching treatment.

Canvas Table Plant.—At the Mitchell and Mussigbrod mill at Garnet, Montana,[21] a canvas table plant has been used with success. The ore milled is a sulphide carrying gold which is crushed to 30-mesh by stamps; the pulp passes over silver-plated copper plates, thence to three vanners, thence to two Wilfleys, and thence to a canvas table, which is the old German *Kehrherd* consisting of an inclined floor 34 ft. long by 38 ft. wide, with a slope of 1 in 10. The runs are 2 ft. wide, and while one is being swept, two others are shut off and are being cleaned by wash water; the sweeping of 400 sq. ft. of table occupies 30 minutes and requires 260 cu. ft. of clean water. The slimes go to a series of settling tanks and boxes.

The mill treats about 30 tons per day of ore, consisting of quartz with mixed sulphides. The vanner concentrates contain 30% SiO_2, the Wilfley concentrates contain 50% SiO_2, and the slimes about 70% SiO_2. During April, 1901, the three vanners made 43 tons of concentrates of 7 oz. gold per ton; the two Wilfleys produced 7·5 tons of concentrates of 7 oz. gold per ton, and the canvas table 8·5 tons of slimes of 7·33 oz. per ton.

At the Portland direct wet-crushing cyanide mill, Black Hills,[22] the battery pulp runs to a spiral sand pump which elevates it to the slime sand separators. The box now in use, shown in Fig. 4, is about 3×4×5 ft. The inlet *I* is a 3·5-in. pipe from the spiral pump; the outlet *O* is a square covered launder, 12 in. wide and 5 in. high; *D* is the bottom discharge door. When the box fills with sand to *O* it is dumped through *D*. The separation which is given in the table on the following page, has been effected on pulp from twenty 900-lb. stamps, dropping 8 in. 94 times per minute, crushing a siliceous refractory ore through 10-mesh and 20-mesh standard wire screens.

Grund in the Hartz Mountains.[23]—The following changes have been made at the establishments in this locality: the use of 3- and 4-sieve jigs instead of the 2-sieve; the use of rolls instead of stamps. By these changes it is possible at

[20] *Engineering and Mining Journal*, Dec. 7, 1901, p. 753.
[21] *Ibid.*, July 6, 1901, p. 5.
[22] *Mining and Scientific Press*, 1901., Vol. LXXXIII., p. 202.
[23] *Zeitschrift fuer das Berg-, Huetten-, und Salinenwesen*, 1901, Vol. XLIX., p. 382.

the Hülfe Gotteser mill to obtain with jigs, tailings representing 40% of the material treated which formerly when stamps were used were treated by an

	Battery Pulp.		Sands after Separation.		Slimes after Separation.	
	10 mesh.	20 mesh.	10 mesh.	20 mesh.	10 mesh.	20 mesh.
	%	%	%	%	%	%
On 20 mesh.....	9·00	0·4	21·0	1·00	.....	.....
Through 20 on 30 mesh	17·00	6·0	27·0	15·50	2·0	1·0
" 30 " 40 "	8·25	7·2				
" 40 " 60 "	15·75	17·2	20·0	18·75	3·5	4·0
" 60 " 80 "	9·00	10·4	10·0	16·50	3·0	
" 80 " 100 "	1·75	7·6	1·5	7·75	2·5	1·0
" 100 " 150 "	11·00	10·0	9·0	23·00	14·0	4·0
" 150 mesh.....	28·25	40·8	11·5	16·75	75·0	90·0
	100·00	99·6	100·0	99·25	100·0	100·0

expensive slime separation. The former jig tailings ran from 2 to 8 mm., while the present product runs up to 32 mm. For dressing ores containing heavy spar, the latter is completely pulverized in stamping, whereas with rolls it is crushed, and the resulting rhombohedrons form small particles which can be drawn off from the jigs.

The saving of slimes[24] in the Cœur d'Alêne district has been successfully accomplished on a small scale by operators working independently of the mills. The most successful method so far is to run the tailings into V-shaped settling troughs about 30 ft. long, 2 ft. wide at the top and 2 ft. deep, the overflow operating an overshot water wheel which runs a vanner. This has resulted in activity in procuring water rights, and the large mills are adding to their plants in an endeavor to save more of their ore values. Attention is also called to the fact that the largest loss of values is in the jig tailings and although the matter has been the subject of much thought and consideration, the problem of saving these values is yet to be solved.

The Concentration of Broken Hill (N. S. W.) sulphide ores was described in detail by Mr. T. J. Greenway in THE MINERAL INDUSTRY, 1900, Vol. IX., p. 745.

Gypsum Milling methods are remarkably uniform in Kansas.[25] The gypsum rock and earth from the mine is crushed in breakers and then reduced to flour by flour mills or disintegrators; it is then treated in the calcining kettle, from which it is conducted to bins, thence to bolting cloths and sized, and finally to the shipping department.

Krupp Ball Mill versus Stamps.[26]—A five-stamp battery with a stamp weight of 525 kg. (about 1,165 lb.), falling 160 mm. (about 6·5 in.) with 92 drops per minute crushes approximately 780 kg. (about 1,720 lb.) of hard quartz per hour through a No. 40 screen, requiring 12·5 H.P. A No. 3 Krupp Ball mill crushing wet, with 450 kg. of special steel balls, will pass 1,200 kg. (about 2,650 lb.) of the same quartz through the same screen per hour, using only 9 H.P. A mill for dry crushing, as above described, grinds 800 kg. (about 1,770 lb.) per hour under the same conditions, requires 8 H.P., and if necessary, 2 H.P. extra for the exhaust which separates the dust from the sands.

[24] *Mines and Minerals*, 1900-1901, Vol. XXI., p. 343.
[25] *Engineering and Mining Journal*, Nov. 9, 1901, p. 602.
[26] *Ibid.*, Dec. 7, 1901, p. 759.

Screen tests have given the following results:—

Screen Number. (a)	Stamps.	Ball Mill-wet	Ball Mill-dry.
	%	%	%
Through 40— 60.....	6·5	32.6	29·6
" 60— 80.....	10·5	12·0	12·3
" 80— 90.....	2·0	1·5	1·6
" 90—100.....	11·0	10·0	9·0
" 100—150.....	13·5	9·3	47·5
" 150 and above	56·5	33·8	.....

(a) Probably meshes per linear inch.

Gröndal Ball Mills[27] are used at Pitkäranta, Finland, to pulverize the iron ore as it comes from the Blake breakers. For hard, but brittle material large balls are used, while for tough ore a larger number of smaller balls. The total weight of the balls varies from 1,000 to 2,000 kg.; the diameter of the balls is not over 150 mm. Running at 25 revolutions per minute and using 80 l. of water per minute the following sizes were obtained: grains over 1·0 mm. = 1·7%; between 1 and 0·5 mm. = 1·2%; between 0·5 and 0·33 mm. = 3·8%; between 0·33 and 0·25 mm.=7·5%; between 0·25 and 0·16 mm.=22·4%; between 0·16 and 0·125 mm. = 19·6%; under 0·125 mm. = 43·8%. Using balls of a total weight of 1,500 kg. revolving 28 times per minute, 18 to 20 H.P. is required, which will crush every 24 hours 30 tons of egg sized ore from the breakers through a 1-mm. screen.

A Coarse Concentrating without Sizing Test[28] was made on a Georgia ore carrying gold and silver, and iron, lead, zinc, and copper sulphides, finely disseminated in hard quartzite. The ore was crushed to 8-mesh with a jaw breaker and two sets of rolls, and then treated on a Bartlett table without any sizing. The following results were obtained:—

	Ore.	Concentrates.	Middlings.	Tails.	Percentage Saved in Concentration. Concentration 21·8% of ore.
Copper.....	2·65%	9·30%	2·00%	0·90%	76·5%
Lead.....	2·90%	12·50%	0·30%	0·20%	94·0%
Zinc.....	5·20%	9·10%	5·00%	4·00%	38·1%
Gold (oz. per ton).....	0·18 oz.	0·72 oz.	0·06 oz.	0·03 oz.	92·8%
Silver (oz. per ton).....	1·22 oz.	4·08 oz.	0·56 oz.	0·41 oz.	72·9%
Weight.....	4,850 lb.	1,059 lb.	468 lb.	3,323 lb.	.....
Percentage of Total Weight	100·00%	21·8%	9·6%	68·6%	.....

The results of crushing and sizing tests made on various ores with different classes of crushers have been carefully tabulated, and are embodied in 16 tables given by G. Bonsall Porter.[29] In the two following tables the crushers used were a 9×12-in. Dodge breaker, a 3·5-ft. Huntington mill, a pair of 16×10-in. rolls, a Gates standard sample grinder, and a 5-stamp battery.

A Bolivian tin dressing mill[30] was recently equipped with rock-breakers, rolls, Huntington mills and Frue vanners. The general practice consists of crushing with stamps, sizing by trommel, washing in stationary buddles (rectangular pits), then on round buddles and finally on slime tables; jigs also are used.

[27] *Oesterreichische Zeitschrift*, 1901, Vol. XLIX., p. 429.
[28] *Mining and Scientific Press*, 1901, Vol. LXXXII., p. 5.
[29] *Journal of Canadian Mining Institute*, 1901, Vol. IV., p. 205.
[30] *Annales des Mines*, 1901, Vol. XIX., p. 186.

GOLD QUARTZ, FROM HALIFAX COUNTY, NOVA SCOTIA.

Name of Crusher.	Over 14 mesh.	Under 14 mesh.	Sizing test of material below 14-mesh. 14 to 18	18 to 24	24 to 40	40 to 60	60 to 70	70 to 100	100 to 150	150 to 200	Under 200 mesh.	Remarks.
	%	%	%	%	%	%	%	%	%	%	%	
Dodge	78·4	21·6	17·1	9·3	20·4	15·2	12·3	2·8	10·3	9·3	3·3	Set at 0.5 in.
Rolls	35·8	64·2	21·8	11·3	17·4	6·4	5·7	5·6	20·6	6·5	4·7	Rolls touching.
Huntington		100·0	....	....	0·6	10·0	21·3	17·4	43·6	4·6	2·5	Crushing through 40-mesh.
Sample Grinder		100·0	....	0·6	6·3	16·1	26·0	16·9	24·4	5·3	4·4	
Stamps		100·0	....	....	....	a2·0	9·3	14·3	....	74·4	....	Crushing through 40-mesh.

(a) 50-mesh sieve used in place of 60-mesh sieve.

COAL.

Name of Crusher.	Over 14 mesh.	Under 14 mesh.	Sizing test of material below 14-mesh. 14 to 18	18 to 24	24 to 40	40 to 60	60 to 70	70 to 100	100 to 150	150 to 200	Under 200 mesh.	Remarks.
	%	%	%	%	%	%	%	%	%	%	%	
Dodge	94·83	5·17	36·1	19·2	23·2	a1·3	10·6	1·9	....	7·7	....	Anthracite.
Rolls	45·5	54.5	26·0	14·0	18·0	8·0	7·0	7·0	9·0	6·0	5·0	"
Dodge	83·0	16·0	25·0	14·0	18·0	8·0	8·0	5·0	7·0	7·0	5·0	Bituminous.
Rolls	65·3	34·7	31·0	12·0	20·0	8·0	7·0	8·0	9·0	8·0	2·0	"

(a) 50-mesh sieve used.

MAGNETIC CONCENTRATION.

At Pitkäranta, Finland,[31] with ore containing approximately 30% Fe, and 4 to 5% S, 80 per cent. of the iron content is made up of magnetite, the particles being scarcely larger than 1 mm. The sulphur compounds are blende, pyrrhotite, pyrite and chalcopyrite. The gangue is hard serpentine and malacolite, and contains from 8 to 9% Fe. The plant consists of four Blake breakers, eight Gröndal ball mills, and eight Gröndal magnetic separators. The capacity depends upon the contents of the feed; with the ore described above the capacity is about 30 tons per day; if a greater quantity is fed the separation is unsatisfactory. The separators require a current of six amperes with 31 volts. An average product with 61% Fe contains 0·6% S; with 66% Fe contains 0·24% S and with 68% Fe contains 0·18% S. The finished product is briquetted and heated to 1,200°C. Without this heating the briquettes could only be handled cautiously for fear of breaking.

Magnetic Separation by the Mechernich Separator.[32]—The following results were obtained in experimenting with a blende ore carrying barite: with blende fines using 18 volts and 20 amperes, the zinc contents were raised from 40·29% to 49·04%, while the barite contents were reduced from 12·52% to 1·95%; 95·2% of the zinc contents were recovered. With blende fines middlings, the zinc content was raised from 31·73% to 39·66%; this result would have been better had the material been dryer. With blende sands middlings, screened into two products, 0·5 to 1 mm., and 1 to 1·5 mm., using 21 volts and 41 amperes, the zinc content was raised from 41% to 51%; the barite content lowered from 5·6% to 0·5% and 78% of the zinc was saved.

[31] *Oesterreichische Zeitschrift*, 1901, Vol. XLIX., p. 429.
[32] *Berg- und Huettenmaennisches Jahrbuch*, 1901, Vol. XLIX., p. 242.

The Waring System of Magnetic Concentration[33] is in use at Webb City, Mo., for cleaning zinkiferous concentrates of copper and iron pyrites. The concentrates are dried, put through a 0·25-in. sieve, passed to a mechanical calciner which is adapted to desulphurize partially the pyritic material and to change ferric oxides and ferrous carbonates, chalcopyrite, etc., to the magnetic condition, without in the least degree affecting the blende or such other minerals as are to be separated by magnetic repulsion. The hot material is mechanically cooled and delivered to a Waring separator of the drum type, falling into the intense magnetic field of the peculiarly arranged annular grooves of the machine, from which the diamagnetic blende is expelled by magnetic repulsion aided by centrifugal force; while every particle of magnetic material, no matter how low its magnetic permeability, remains attached to the polar rings, and is released upon arriving at the opposite side of the axis. The first product is quite free from magnetic particles and requires no further treatment. The paramagnetic product passes to a magnetic classifier, which removes the different minerals according to their magnetic permeability. Ordinary pyritiferous zinc ores from Galena, Kan., averaging 44% Zn, 15% Fe (valued at less than $10 per ton in the ore market), gave a product containing 64% clean blende assaying 64·2% Zn, the burnt pyrites contain 2·8% Zn; the value of the blende product (0·64 ton) from one ton of ore was $17·92.

A test on a lot of mixed Colorado sulphide ore concentrates (41 tons) worth $3·30 a ton at the mine, gave 19·5 tons of zinc concentrates worth $17 per ton, and 21 tons of copper-iron concentrates worth $18·45 per ton. The cost of magnetic concentration was $1·10 per ton. The following table gives the values contained in the original material and the resulting products.

Original Contents.		After Magnetic Concentration.	
		Zinc Concentrates.	Copper-Iron Concentrates.
Gold....	0·21 oz. per ton.	0·02 oz. per ton.	0·4 oz. per ton.
Silver...	5·10 " " "	2·00 " " "	10·0 " " "
Copper.	8·00%	0·50%	15·0%
Lead....	1·60%	1·20%	2·0%
Zinc....	31·20%	60·20%	5·1%
Iron	25·00%	1·20%	46·0%

The Wetherill Separator,[34] treating an ore consisting of galena, blende, spathic iron ore (containing 12% Mn), with a quartz gangue has yielded a blende product with from 42 to 46% Zn, while the spathic iron contains only from 1 to 3% Zn. The tension is 65 volts, and the magnets work with a current of from 5 to 8 volts and from 12 to 16 amperes. With eight men, from 3 to 3·5 tons of ore are treated hourly at a cost of 1s. 5d. ($0·34) per ton.

Magnetic Concentration[35] has been tried on the Broken Hill, N. S. W., sulphide ores, but commercial conditions prevent its use.

Roasting Zinc Ores.—In the removal of iron from zinc blende, Dr. Wm. B. Philips[36] finds the roasting temperature to be a very important factor; if overroasted much iron is thrown over into the zinc heads; it is not necessary to

[33] *Engineering and Mining Journal*, Sept. 14, 1901, p. 328.
[34] *Glueckauf*, 1901, Vol. XXXVI., p. 1039.
[35] THE MINERAL INDUSTRY, 1900, Vol. IX., p. 752.
[36] *Engineering and Mining Journal*, Nov. 30, 1901, p. 710.

remove more than one-third of the sulphur in roasting to obtain the best results.

Strength of Electric Current.—E. Langguth[37] considers that the currents used in the electro magnetic separation of ore must have as low an intensity and as great a density as possible, that is to say, intense magnetic fields. The ore must be passed before the separating poles steadily and at as short a distance as possible; and the rate of speed at which this is done must depend on the magnetizability of the ore particles. Finally, the separation must be effected in homogeneous magnetic fields.

At Naeverhaugen, Norway,[38] a red hematite ore containing from 40 to 60% Fe is being concentrated.

Concentration by static electricity[39] is the object of a recent patent; the device consists of an endless, electrified traveling belt, fitted with screen capable of electrical repulsive action. Above the belt are two suction hoods to draw off the electrified particles.

The Wetherill Magnetic Process of Ore Concentration is described in detail by H. A. J. Wilkens, elsewhere in this volume.

Pneumatic Concentration.

Crown Dry Concentrating System.[40]—After crushing the ore with rock breaker and rolls arranged to give minimum fines, and sizing through a set of sieves ranging from 40- to 180-mesh, the different sizes of pulp are sent to the concentrator proper, which consists of a woven, corrugated, inclined belt traveling through a closed box with an air chamber under the superior portion. At the head or elevated end of the belt a blower is placed which discharges air horizontally into this chamber. The whole is mounted on a shaking table having a rapid vibratory motion to keep the pulp in active vibration. The air pressure in the box under the belt can only relieve itself through the interstices of the woven belt, and as this is running at an angle of 15° or less, the horizontal air column strikes it at an acute angle and passing through the belt displaces the lighter and worthless grains and causes them to move toward the lower or waste discharge, while the heavier and valuable portion being unaffected is carried on to the upper or concentrate discharge. A recovery of from 85% to 95% of the total sulphides is claimed. A 100-ton plant is in process of erection at the Mayday mine, Tintic district, Utah.

Oil Concentration.

The Elmore Process.[41]—In treating 5,000 tons of Glasdir ore, assaying 1·5% Cu, 20 to 30 g. silver, and 2·5 g. gold per ton, an extraction of 80% of the values was obtained; the concentrates averaged 10% Cu, 250 g. silver and 25 g. gold. The cost of treatment, including crushing, was $1·44 per ton; the

[37] *Zeitschrift fuer Elektrochemie*, 1899-1900, Vol. VI., p. 500.
[38] *Journal of the Iron and Steel Institute*, 1901, Vol. LIX., p. 354.
[39] *Electrical Review*, 1901, Vol. XXXVIII., p. 490.
[40] *Engineering and Mining Journal*, June 1, 1901, p. 694.
[41] *Oesterreichische Zeitschrift*, 1901, Vol. XLIX., p. 307.

oil consumption was from 2 to 2·5 gal. per ton of ore, and the sp. gr. of the oil was 0·9.

An oil plant has been ordered for the Independence mine, Colo., and an option has been taken by Mr. Chas. Butters, representing the Elmore Co., on the tailings dump of the Mammoth Mining Co.,[42] Tintic, Utah, who will give the process a thorough trial. The accompanying table will show what this process has done in the laboratory on different kinds of ores.

RESULTS OF LABORATORY TESTS MADE BY THE ELMORE ORE CONCENTRATING PROCESS ON VARIOUS ORES, SLIMES, TAILINGS, ETC.

Description of Ore.	Original Assay.			Assay of Concentrates.			Assay of Tailings.			Percentage of Values Recovered in Concentrates.			Ratio of Concentration.
	Copper	Silver.	Gold.	Copper	Silver.	Gold.	Copper	Silver.	Gold.	Copper	Silver.	Gold.	
	%	Oz. P. T.	Oz. P. T.	%	Oz. P. T.	Oz. P. T.	%	Oz. P. T.	Oz. P. T.	%	%	%	
1. Copper Ore	7·1	3·9	0·61	14·6	8·0	1·28	(a)	(a)	(a)	95·0	91·0	92·0	2 to 1 b
2. Copper Ore	7·6	2·67	0·27	10·9	3·6	0·39	(a)	(a)	(a)	94·0	90·0	94·0	1·5 to 1
3. Copper Ore	3·9	0·53	0·64	19·1	2·7	3·00	(a)	0·07	0·09	94·0	98·0	90·0	5·2 to 1
4. Copper Ore	3·6	0·73	0·24	11·5	2·5	0·60	(a)	(a)	(a)	97·0	98·0	96·0	3·1 to 1
5. Tailings from a Water Concentrating Plant	1·56	.....	.....	7·8	.....	.....	0·11	.....	.....	84·0	.....	.....	5 to 1
6. Copper Ore	3·40	1·74	0·19	8·0	5·0	0·51	(a)	(a)	(a)	91·0	93·0	95·0	2·5 to 1
7. Telluride Gold Ore	.....	0·10	1·27	.....	.....	6·1	.....	.....	0·35	.....	.....	96·8	5·5 to 1
8. Telluride Gold Ore	.....	0·24	3·05	.....	1·5	18·3	.....	(a)	0·19	.....	.....	97·5	7 to 1 b
9. South African Gold Ore	.....	.....	0·91	.....	.....	3·79	.....	.....	(a)	.....	.....	96·0	3·5 to 1
10. Antimonial Gold Ore Tailings	.....	0·05	0·618	.....	.....	6·13	.....	.....	.....	.....	.....	98·0	10 to 1
11. Copper Ore	3·0	6·5	.....	8·40	16·2	.....	0·30	0·90	.....	90·3	80·0	.....	5·1 to 1
12. Silver Ore	1·15	32·0	.....	3·0	65·4	.....	0·30	7·0	.....	85·2	87·3	.....	2·4 to 1 b
13. Magnetic Oxide, with Copper Pyrites	11·5	.....	.....	29·0	.....	.....	0·60	.....	.....	94·0	.....	.....	2·5 to 1
14. Copper Ore	2·2	.....	.....	9·0	.....	.....	0·45	.....	.....	80·0	.....	.....	5 to 1
15. Copper Ore	4·3	1·90	(a)	12·1	5·6	0·66	0·08	(a)	(a)	97·0	98·0	.....	3·1 to 1
16. Copper Ore	2·8	1·78	(a)	10·8	7·4	.....	0·05	(a)	(a)	98.0	99·0	.....	3·1 to 1
17. Copper Ore	3·6	1·41	0·31	8·1	3·5	0·75	(a)	(a)	(a)	96·0	95·0	93·0	3 to 1
18. Antimonial Gold Tailings	.....	0·14	0·516	.....	0·6	3·8	.....	(a)	0·17	....	90·0	77·0	7 to 1
19. Antimonial Gold Slimes	.....	0·14	0·232	.....	1·5	2·4	.....	(a)	(a)	....	90·0	94·0	7 to 1
20. Magnetic Oxide, with Copper Pyrites	3·6	.....	.....	14·5	.....	.....	0·33	.....	.....	92·0	.....	.....	4·4 to 1
21. Slimes from Silver Mines	.....	16·2	0·2	.....	153	2·0	.....	4·1	(a)	....	77·0	90·0	12·5 to 1
22. Copper Ore	4·4	.....	.....	15·31	.....	.....	0·02	.....	.....	89·6	.....	.....	3·5 to 1
23. Pulp from Battery Table (Silver Ore)	.....	23·5	0·35	.....	220	3·5	.....	6·0	0·1	....	76·5	74·8	12·5 to 1
24. Magnetic Oxide, with Copper Pyrites	3·20	.....	.....	13·10	.....	.....	0·08	.....	.....	98·0	.....	.....	5 to 1
25. Copper Pyrites in Quartz	1·80	.....	.....	9·00	.....	.....	0·15	.....	.....	93·0	.....	.....	6·25 to 1
26. Copper Pyrites in Slate	2·80	.....	.....	15·65	.....	.....	0·04	.....	.....	98·7	.....	.....	7·5 to 1
27. Transvaal Banket	.....	0·20	0·327	.....	2·55	3·627	.....	0·067	0·039	....	70·67	88·85	12·5 to 1
28. West Australian Gold Ore	....	1·30	1·147	.....	3·25	13·060	....	1·000	0·025	....	21·90	97·80	12·5 to 1
	Hg.			Hg.			Hg.			Hg.			
29. Cinnabar (Quicksilver Ore)	0·50	.....	.....	11·00	.....	.....	0·023	.....	.....	96·0	.....	.....	21 to 1
30. Cinnabar (Quicksilver Ore)	1·24	.....	.....	13·10	.....	.....	0·075	.....	.....	95·2	.....	.....	12 to 1
31. Cinnabar (Quicksilver Ore)	1·75	.....	.....	19·00	.....	.....	0·200	.....	.....	90·0	.....	.....	16 to 1

(a) Trace. (b) Nearly.

The advantages claimed for this process are as follows: (1) saves the finest slimes; (2) can be used after wet crushing without classification; (3) requires little labor and power; (4) relatively low cost of installation, and small floor space; (5) low operating cost; (6) small water consumption; (7) clean concentrates; the presence of oil is no disadvantage; (8) gives separations impossible with water, such as copper pyrites from magnetite; (9) mechanical appliances

[42] *Engineering and Mining Journal*, June 29, 1901, p. 836.

permit a clean plant, and oil loss is from 1 to 3 gal. per ton of ore; (10) the plant can be enlarged easily; and (11) can work on a great variety of ores.[43]

Coal Washing.

At the Donk Bros. Washing Plant,[44] designed to wash 60 tons per hour, the raw coal is divided into four sized products by a triple-jacketed screen. The three nut coal sizes go to special jigs which deliver clean nut to the draining elevators and screens. The fine coal goes to a hydraulic grading sizer. This is a V-shaped box having compartments corresponding to the fine coal jigs. Each different product from the box goes to a special fine jig having a special crushed feldspar bed. The clean coal is sluiced from the fine jigs to the drying screen having 0·125-in. openings. The refuse from the nut coal jigs and the waters draining from the nut coal drying screens and the same for the fine coal go to separate sludge elevators which elevate the refuse while the fine coal dust drains out with the water (through the perforations in the buckets), and the fine coal dust is afterward settled out and saved. The clarified water is pumped over again through the circuit.

Attention is called to the following special features of this plant: (1) the extreme and careful grading into different sizes, and washing each size in a jig especially made and adjusted for it; (2) the arrangement of the whole plant with a view to minimizing labor, three men only being required to run it; (3) the effective arrangement for settling the water, and the automatic and continuous removal therefrom of sludge and refuse, clarifying the water, and saving all the fine coal dust; (4) the effective arrangement for drying the washed coal.

New Coal-Screening and Washing Plant at a Belgian Colliery.[45]—Coal up to 2·5-in. size is screened, the total output passing to coking ovens. There are five products from the four-part conical screen; the finest product or dust, is passed without washing via elevators, etc., directly to the storage bins; the four larger sizes are sluiced down chutes to the washing plant arranged on the Francou system. The largest three of these sizes are treated each in a separate washing tank (jig). The fourth or smallest size (next to the dust) is treated in two washing tanks. The stones (waste) from all five of these washing tanks are washed over again in a sixth tank and are then sent to a storage bin. The fine slates traversing the filtering bed and the washing table do not contain any coal whatever; but are discharged to settling tanks. The washed coal is drained on sloping tables and in perforated sloping troughs up which they are elevated and finally crushed in a Deville crusher and elevated to the storage bins. The washed coal must not contain more than 8% moisture on leaving the washing plant, in order that it may be crushed and delivered to the storage towers dry enough for coking.

The Screening of Anthracite.[46]—At the breaker of the Delaware, Lackawanna and Western Railroad, the entire product, barring the fines, can be turned out

[43] *Engineering and Mining Journal*, June 1, 1901, p. 691.
[44] *Mines and Minerals*, 1901, Vol. XXII., p. 55.
[45] *Colliery Guardian*, 1901, Vol. LXXXII., p. 859.
[46] *Ibid.*, p. 630.

at any desired size merely by a convenient system of by-passes which chute the sizes larger than are desired back to the crusher and screens.

Coal briquetting[47] is carried on as follows: the undersize from an 8-mesh revolving screen is conveyed to a heater; the oversize goes to rolls and thence to a heater; the temperature is brought up to about 300°F.; the coal then passes to a double bladed screw conveying mixer, at the bottom of which hot pitch is introduced. The mass is thoroughly mixed and conveyed to the press. Briquettes are made from United States bituminous coals with as low as 4% binder; some Western lignites can be successfully briquetted with 6%. The pressure can be regulated up to 5 tons per sq. in. Machines are of 12, 25 and 50 tons capacity in 10 hours. The largest briquettes are 3 in. in diameter and 3 in. long.

Clay Washing.

This subject has been very well described by Prof. H. Ries, in his article, "Clay," in The Mineral Industry, 1901, Vol. IX., p. 107.

[47] *Colliery Guardian*, 1901, Vol. LXXXI., p. 38.

LIQUEFIED CARBONIC ACID GAS.

By Auguste J. Rossi.

Occurrence.—Carbon dioxide, carbonic anhydride, or as it is commonly but erroneously called, "carbonic acid gas," is widely distributed in nature. In the gaseous condition, it forms an essential element of the atmosphere to the extent of four volumes in 10,000; and it is given off spontaneously from the fissures of rocks in certain grottoes; it is also found at the bottom of the shafts of a few lead mines in France. Under the influence of light, plants decompose the carbon dioxide of the atmosphere, retaining the carbon to aid in building up the plant structure and setting free the oxygen; carbon dioxide is also found in soils, from which it is extracted by rain and other surface waters. It is the ultimate product of the fermentation of many liquids as well as of the destruction of organic matter and it is a product of the combustion of all carbonaceous fuels. It occurs dissolved in many mineral waters as alkaline carbonates. In solid combination, it forms the carbonate groups of minerals embracing limestones, calcite and many important ores of the metals,—iron, copper, lead, zinc, etc.

Properties.—Carbon dioxide is a colorless gas of pungent taste and while not supporting combustion or respiration it acts passively by excluding the proper amount of air. It has no corrosive action on metals or fabrics. The gas is heavier than air, having a sp. gr. of 1·5241 at standard temperature and pressure (0°C. and 760 mm.).

It is soluble in water which can absorb about two volumes at 32°F. and atmosphere pressure, the solubility increasing as the pressure increases and the temperature diminishes. It can be compressed to a colorless and very mobile liquid of a sp. gr. nearly that of water, *viz.:* 0·9474 at 0°C.; 0·8825 at 42°F.; 0·7385 at 65°F., and only 0·60 at 86°F. The liquid is slightly soluble in water and boils at —78·5°C. (—108°F.) at the normal pressure of the atmosphere; at 13°F. under a pressure of 17 atmospheres (255 lb.) and at 77°F. under 66 atmospheres (about 1,000 lb. per sq. in.).

When a mixture of liquid carbon dioxide and ether is brought under the vacuum of an air-pump, the temperature drops to —110°C. (—110°F.), which is sufficient to solidify the liquefied acid to a transparent ice-like mass. The latent heat of evaporation of the liquid at 0°F. is about 125 thermal units per pound, diminish-

ing very rapidly as the temperature rises and falling to 19·28 thermal units at 86° F.

The liquefaction of carbon dioxide gas was first made by Faraday as a laboratory experiment and later by Thilorier to an important amount in an apparatus which has since become classic and which perfected by Neuterer of Vienna and Bianchi, could furnish several pounds of the liquid. In a general way the principle of the apparatus is to generate the gas in a closed vessel by any well-known chemical reaction, the gas itself making the pressure required to liquefy it; in this form it is distilled from the generator into a receiver of iron or steel connected with the generator and properly cooled in a freezing mixture. The receiver, generally a cylinder capable of resisting high pressure, is provided with the proper valves and, according to its position, can furnish gas if the valve be opened, or liquid if the receiver be inverted. In the latter case, the liquid carbon dioxide escaping will vaporize instantly in the air, producing so low a temperature by the evaporation and expansion of the gas produced that a part of the liquid is solidified in the form of a snowy-white substance which may be collected in a proper receptacle as it flows from the cylinder. This "snow" can readily be kept for 12 hours or more in a woolen cloth; it gradually returns to the gaseous state, producing an intense cooling effect by the double change of state from solid to liquid and liquid to gas. Two pounds of liquid carbon dioxide can readily furnish 1 lb. of snow. Many ingenious contrivances have been devised to produce important quantities of this snow.

Carbon dioxide, being a weak acid radical, it is readily obtained in the gaseous state by the decompositions of the carbonates by a stronger acid.

Applications and Uses.—In the gaseous state carbonic dioxide has had for years an important use in the manufacture of beverages charged with the gas under pressure, as water, wines and the like. The apparatus formerly adopted, while well constructed for the purpose, was cumbersome, and called for special manipulations which obviously could be avoided if the gas could be supplied in a liquid form which could give out by its evaporation several hundred times its volume of gas. For many years, however, liquid carbon dioxide remained a curiosity of the laboratory, but for the last 20 years its production has become quite common, thanks to the development of the mechanical arts in general and to the advent of steel in particular, which furnished cheaply vessels capable of sustaining the great pressure generated. It was first prepared on an industrial scale in Germany by Dr. Raydt, of Hanover, who in 1879 used it for the novel purpose of floating a sunken German ironclad, the Grosser Kurfürst, which had been sunk by a collision in the channel. The necessary amount of gas was evolved in strong impervious canvas bags and the submerged vessel was raised to the surface. Since that time liquid carbonic dioxide has entered into the industrial practice, and in 1887 its manufacture in Berlin alone amounted to one ton daily. Notwithstanding the enormous pressure of from 800 to 1,000 lb. per sq. in. prevailing in the flasks in which it is stored, it can be safely handled, and in Europe no accident has attended its use. The receivers are of drawn or lap-welded steel cylinders, tested to a pressure of 3,000 to 3,500 lb. per sq. in. (250 atmospheres). They contain 20, 30 and 36 lb. of liquid and are filled

at a pressure of about 800 lb. The empty 20-lb. size cylinder weighs 90 lb. and measures 43 in. in height by 7 in. in diameter. The bottom is made concave and the top is drawn to a neck in which a proper screw plug is fitted. At a temperature of about 68°F. the pressure inside is 849 lb. per sq. in., and at 86°F. about 1,000 lb. per sq. in. In some tests made about a year ago by the Scotch & Irish Oxygen Co., of Glasgow, vessels of this type filled at a pressure of 1,800 lb. per sq. in. were allowed to fall 35 ft. on to iron blocks and otherwise severely treated without damage further than bending and a certain loss of shape.

One of the principal applications of liquid carbon dioxide is for the manufacture of carbonic or "soda" water and other beverages. By its use not only are the manipulations considerably simplified, but the amount of carbon dioxide introduced can be accurately regulated at pleasure. One pound of liquid carbon dioxide will produce about 8 cu. ft. of gas at atmospheric pressure, that is, over 500 times its own volume. The property of carbon dioxide not to support combustion indicates its use as a fire extinguisher in the liquid state, since in a small volume of the latter is disposed a large amount of gas, and its price, low as it has become, appears to be the only objection to its use for this purpose on a large scale. A portable apparatus containing liquid carbonic dioxide would prove very effective.

On board vessels, in case of conflagrations in the hull or elsewhere, the use of liquid carbonic dioxide would be of great value, as a large volume of gas would be immediately available and the cylinders would occupy but little room on or between decks. The great advantage of carbonic dioxide is that it does not injure the fabrics in any way. It is remarkable that its application in this direction has not become more general. It has been used with great advantage to extinguish an underground fire in a certain colliery.[1] The building off of the heading not having succeeded in smothering the conflagration, resource was had to liquid carbon dioxide. Ten 20-lb. cylinders of the liquid were connected with a 2-in. drain pipe having 0·75-in. branches placed at intervals of about a foot, and the flow of gas directed on the fire. The results were entirely satisfactory.

As the liquid evaporates cold is produced and the low temperature at which the gas escapes from the cylinder is in itself a favorable factor, but, as this low temperature may cause the discharge valves of the receivers to choke when the gas is generated, the cylinder, while being emptied, may be immersed in water kept lukewarm by a jet of steam, a proceeding however which is not unattended with danger.

In England and Germany liquid carbon dioxide costs 4@5c. per lb., and it is considered by Cowles that in an atmosphere containing 15% CO_2 flame will be extinguished. On this basis the test of carbonic dioxide for fire extinguishing purposes is about 2% per cu. yd. of space to be filled. This may appear a large figure, but in case of a fire in a mine, flooding by water involves a subsequent pumping as well as the stopping of mining operations and may amount to more than the cost of the carbon dioxide. In an ordinary fire in a town it is a question if the spoiling of goods by water would not amount to

[1] Abstract of a paper in *Transactions of the Federated Institute of Mining Engineers*, reproduced by the *Engineering and Mining Journal*, Vol. LXVIII., No. 6, Aug. 5, 1899.

more than the cost of liquid carbon dioxide. On a limited scale[2] liquid carbon dioxide has been used for cooling test pieces of rails, wheel-tires, stoves, etc., by wrapping the pieces in several thicknesses of coarse cloth, placing them in a tight and well insulated box and directing on them a jet of liquid carbon dioxide, which, by solidifying packed them in the snow thus formed. Carbon dioxide gas has been suggested as a means of preserving perishable articles in transportation in cars made air-tight by a zinc lining.[3] By creating an atmosphere of the gas in the cars, air,—the cause of the decay,—is excluded. In this line a relative success has been secured. Beef meat has been thus preserved for eight days in summer without change, and for 14 days with but little change; but mutton and veal would not keep. However, fruits have been sent without deterioration from California to Chicago in cars containing an atmosphere of carbonic dioxide, at a cost of $125 per car; cylinders of liquid carbon dioxide were used to create and maintain the antiseptic atmosphere. Butter also has been preserved in the same manner. It is a question however whether this use of liquid carbon dioxide will ever be of commercial benefit.

As the gas is supplied from the cylinders at a high pressure, it has been suggested to use it to propel torpedo boats, street vehicles, locomobiles, or the like. The negative chemical properties of carbon dioxide render it particularly adapted for purposes of this kind.

Liquefied carbon dioxide is now being used for raising beer[4] instead of the ordinary pump. A valve is attached to the cylinder, which reduces the pressure to about 4 lb. per sq. in. or whatever pressure is required to raise the beer from the cellar to the tap. An air-tight connection is made for the top of the barrel and the pressure not only elevates the beer in good condition, but it is said to improve it as the level gets lower in the barrel. The antiseptic qualities of the gas makes its use preferable to that of the ordinary beer engine. Liquid carbon dioxide has been found advantageous in bottling beer also, and beer thus bottled matures in three days instead of three weeks.

The liquid has found a very extensive application for refrigerating purposes, either for making ice or for cooling rooms for the preservation of perishable articles,—packing-houses, abattoirs and the like; and it is now used in mechanical refrigeration in competition with ammonia, sulphur dioxide, methyl chloride, and other volatile liquids. Without describing the mode of working of the various refrigerating machines or stating the volatile liquid used, the *modus operandi* is the same; they differ only in the details of the mechanical contrivances employed to meet the special requirements of each liquid. Liquid carbon dioxide as a refrigerating agent has the advantage of requiring the smallest capacity of compressing and exhausting pump for a given amount of cold obtained, but it does this at the expense of very considerable pressure necessitating particularly strong and well-built machines. In this particular line of application objections have been raised against its use in very warm climates. There appears to be for each fluid a temperature at or above which it passes into the gaseous state no

[2] M. Ph. v. Haller, in *Industrie Zeitung*, of Riga.
[3] *Ice and Refrigeration*, Vol. VII., p. 236, and others.
[4] *Ibid.*, Vol. IX., p. 254.

matter to what pressure it is subjected.[5] This temperature is called "the critical point," and above it the fluid is considered uncondensible gas. The critical point for carbonic dioxide has been determined by Andrews at 86°F.; that is, according to our present knowledge. Above this temperature carbon dioxide can only exist in the gaseous form and cannot be liquefied by removing the latent heat of evaporation, whatever may be the pressure. This seems to be in contradiction with actual action of carbon dioxide refrigerating machines operating in the tropics at temperatures above 86°F. even as high as 94°F. These machines are stated to give fully ten times the refrigerating effect which could be expected from carbon dioxide if it were acting simply as an uncondensible gas at these temperatures. Windhausen is the authority for this statement, which is fully confirmed by other large builders of machines, over 40 being now in successful operation in the tropics or on board of refrigerating ships at temperatures above 86°F. While a detailed discussion of this question which has somewhat puzzled technical engineers and scientists is hardly in place here, it has been deemed advisable to state briefly the two sides of the question.

A scheme has been proposed to use liquid carbon dioxide as a refrigerating agent for a "pipe system" to supply cold in the same manner as heat or steam is furnished in certain cities. It consists in laying under ground special pipes, well insulated, in which the liquid would be circulated and delivered to the customers for the purpose of cooling ice-boxes and refrigerators or even of making ice for their own use. Without entering into details it can be conceived that if liquid carbon dioxide fills certain receivers at the customers' place from the distributing pipe, it can be tapped as a gas at a very low temperature in a system of coils properly disposed in the refrigerator; the evaporation in the receiver itself producing also an intense available cold and the gas resulting from the evaporation could be returned to the works to be liquefied anew after having produced the desired cooling effect, or wasted, if the carbonic dioxide could be produced as a by-product at a nominal price. Considerable capital has been invested in a certain city in the West for such a scheme; pipes were laid down and works constructed, but so far no official notice of its success has come to hand. Among possible causes of failure are the many difficulties inherent in a "pipe system" in general, which even with steam has not been particularly successful.

Manufacture.—Liquid carbon dioxide can be manufactured in four ways:—

(*A*) Directly from the natural gas.

(*B*) Indirectly from the carbon dioxide gas generated during the fermentation of liquids.

(*C*) Indirectly from the gas resulting from the combustion of coke or other fuel.

(*D*) Indirectly by the decomposition of the carbonates, dolomite, calcite, magnesite, and even ammonium carbonates.

Tests made by Mr. Simon Thomas[6] show that the liquid carbon dioxide obtained by these methods is very pure, the product from the natural gas being

[5] "Compend of Mechanical Refrigeration," by J. E. Siebel, and discussion of the question in *Ice and Refrigeration*, Vol. I. to XI., by sundry writers.

[6] *Moniteur Scientifique*, quoted by *Génie Civil*, Vol. XXXVII., No. 21.

if anything the purest. The impurities are mainly carbon monoxide (CO) and watery vapor. The following analyses are quoted of the product obtained by the different processes:—

	Vessel Content.	Residue.	
	Kilograms.	Weight. Grams.	Composition.
Process A	10·3	0·52	0·517 H_2O. 0·003 — ?
Process B	Practically	the same	as "A."
Process C	60	0·5	Contained water.
Process D.—Magnesite	10·1	1	Water and trace of CO.
Process D.—Calcite	9·9	8·5	Water and trace of CO.

Process A, Using Natural Gas.—The conditions under which the natural gas escapes from the earth determine the particular mode of collection. The collected gas is practically pure, containing but little watery vapor. It is carried through pipes from the source of supply to a dessicating tower containing calcium chloride which frees it from moisture; an intermediate gas holder may be used to store it. From the tower it passes to the compressors and is liquefied. The product is then filtered through charcoal and stored in steel cylinders for use.

Process B, Using Gas Collected from the Fermentation of Beer or Other Liquids.—A description of this process, first carried out at the Guiness brewery, in 1890, is given by A. Marcet, as follows:[7] The quantity of carbon dioxide gas evolved during fermentation is approximately equal in weight to the alcohol produced. In breweries the rapid evolution of the gas begins in about 20 hours, and in distilleries in about 6 or 8 hours after "pitching" and for some time after the evolution is sufficiently rapid and regular to allow it to be drawn off by pumps without fear of entangling the air. If air is drawn into the compression pumps, however, it can be removed by a special release valve. For collecting the gas the ordinary parachute or "skimmer" is used having a hoisting gear which permits it to be kept above the head of the yeast. The level of the carbonic dioxide gas in the vat is ascertained by an ordinary collodion air balloon, which floats on the upper surface of the stratum of gas. The collection is stopped as soon as the evolution of gas becomes slow. A three-stage compressor is used, the gas being pumped after the first stage (15 lb. per sq. in. compression) by passing through strong sulphuric acid water and a weak solution of potassium permanganate. To purify 100 lb. of carbon dioxide gas requires 5·5 lb. sulphuric acid, 0·75 oz. of permanganate and 0·75 oz. sodium carbonate. The pressure in the third stage reaches about 60 atmospheres; from this stage the gas passes to the condensing coils, which are cooled by a circulation of water, and is there liquefied. The intermediate collecting vessel and the receiver or drum are suspended on special balances (Sattie's), so that the attendant can see at once when they are full. The gas obtained in this way is 99·5% pure and is odorless. The cost of the liquid carbonic dioxide, including labor and interest on capital, is about £3, 10s. a ton, and in 1895 it sold at £18 a ton.

In other breweries Kuhler's method is followed,[8] which consists in placing over the vat when the fermentation is well started, a cover which closes it hermetically.

[7] *Transactions of the Institute of Brewing:* Abstract in *Ice and Refrigeration*, Vol. IX., No. 4, 1895.

[8] *Ice and Refrigeration*, Vol. IX., p. 254, 1895–1896, and others; *Génie Civil*, Vol. XXIX., No. 5, p. 75, 1896.

Pipes from this cover deliver the gas to a gas holder from which it is drawn by a pump and forced through a calcium chloride column to deprive it of its moisture. From this it is discharged under a pressure of 10 atmospheres into a desiccating vessel containing concentrated sulphuric acid. From the desiccator the gas is forced into a water-cooled coil from which a second compressor forces it through a cotton filter, discharging it under a pressure of 70 atmospheres into a steel receiver immersed in cold water. One hectoliter of beer (about 26·5 gal.) will yield 1·5 kg. (3·6 lb.) of liquefied gas.

Process C, Using Gases from the Combustion of Fuel.—At the Da Road Works, Old Fords, England, the process is carried on as follows:[9] The carbon dioxide gas is produced by the combustion of coke in furnaces having two boilers or vats which form a part of the apparatus, the waste gases are passed through scrubbers having a continuous circulation of potash lye, which absorbs the carbon dioxide. This solution then passes to the boilers or vats, where the absorbed carbon dioxide gas is disengaged by heat and subsequently collected, purified, and sent to the compressors. The potash lye thus deprived of its carbon dioxide gas is returned to the scrubbers for further use. The sulphur contained in the coke is transformed into sulphur dioxide by the combustion, and, as the gas would combine with part of the potash solution and waste it, the mixed gases, carbon dioxide, and sulphur dioxide, as they leave the furnace, are washed first in hot and then in cold water, which readily dissolves the sulphur dioxide to the extent of about 35 volumes, the carbon dioxide gas being only sparingly soluble. To wash the waste gases they are pumped into special vessels containing small fragments of marble through which water circulates, first hot in one vessel, then cold in the other; before reaching the washers the hot furnace gases are utilized to heat the wash water by circulation through coils. The gases thus washed and deprived of sulphur dioxide and other impurities are pumped to the absorbing towers, filled with coarse fragments of coke over which flows a continuous supply of lye solution. This solution absorbs the carbon dioxide gas and is collected in a special reservoir from which it is pumped to the boilers or vats, and there deprived of its carbon dioxide gas content. The normal pressure in the boilers is about 5 lb. per sq. in. The purified carbon dioxide gas is collected in a gas holder which supplies water-jacketed compressors of the three-stage vertical type, operated by a 20-H.P. engine. The first compressor is of the double-acting type and compresses the gas to 20 lb. per sq. in., discharging it into a purifier, where the last trace of moisture is removed by calcium chloride. The second compressor, single acting, delivers the gas at 125 lb. per sq. in. to a series of water-cooled coils before it reaches the third compressor, a single-acting one also, where it is compressed to 70 atmospheres (about 1,000 lb. per sq. in.) and liquefied in a properly cooled condenser. These plants have a capacity of 10 tons of liquid carbon dioxide per day.

Process D, Using Gas Produced by the Decomposition of Carbonates.—In the Osborne process bituminous coal is used instead of coke, and the distillation is made at a low temperature, furnishing maximum amounts of coal-tar and am-

[9] *London Engineering*, Oct. 21 1899; reproduced by *Génie Civil* and *Engineering and Mining Journal*, Oct. 21, 1899.

moniacal products. The illuminating and fuel gas produced is utilized to operate the gas engines for the compressors as well as to supply all the power required in the works. The coke remaining in the retorts as the ultimate product of the distillation of the bituminous coal, is used for making water-gas for calcining the limestone (calcite) in closed retorts. These retorts are of a spherical construction and superheated steam is added, which expels all the available carbon dioxide in the calcite. The gaseous product is washed and deprived of moisture before being liquefied by the compressors. The chemistry of the process has been fully endorsed by Prof. B. Stillman, who claims: that the distillation of the soft coal can readily furnish a producer gas of a heating power of 165 thermal units per cu. ft.; that the price of the by-products,—tar and ammonia liquids,—will offset to a large extent the cost of generating the gas; that the use of superheated steam in the calcite retorts will secure a maximum yield of carbon dioxide. This process was used in connection with the pipe line referred to above, and it was estimated that, with coal at $3 a ton, calcite at $2, ammonia liquors at 7c. per lb., coal tar at 5c. per lb., and pure calcined lime at $5 per ton, the liquid carbon dioxide could be furnished to customers at $6 per ton; in fact, as far as cost is concerned, the liquefied gas itself could be considered a by-product—at least it was so stated.

The calcination of limestone, either dolomite or calcite, can be accomplished in intermittent kilns, in kilns with alternate layers of fuel and stone, in compartment ovens (Hofman), or in kilns similar in construction to ordinary brick kilns. In all cases the carbon dioxide gas, more or less impure, is collected, purified and condensed to the liquid state by compressors, as described above. The heat necessary for the decomposition of the carbonate is furnished in many plants by fuel charged with the limestone, but special contrivances have been devised by which the heat can be supplied by producer gas or mineral oils. Kilns or ovens using gaseous fuel give the purest product.

The kiln of Vigreux & Desclosages is used considerably in France.[10] It is circular in shape, and charged with a closed top, like a blast-furnace. Around the circumference are arranged inlets for the producer gas which is burnt by admissions of air in special burners. It is claimed that the limestone is completely calcined after one and a half hours in the zone of heat where the temperature reaches 1,000 to 1,100°C. (1,800 to 2,000°F.). The calcined product is withdrawn every hour or so; at the same time a fresh quantity of stone is charged at the top. The average production for one year of operations was 1,000 kg. of calcined lime for 208 kg. of coke from gas works. The gases at top (carbon dioxide and nitrogen) are collected as in the blast furnace for iron and an analysis gave the following composition by volume: CO_2, 34%; O, 0·5%; CO, 0·24%; N, 65·25%. The difference of specific gravity of nitrogen (less than 1) and of gaseous carbon dioxide (1·5) allows of a ready separation in a gas holder.

Of a still greater industrial importance is the use of magnesite (magnesium carbonate) which yields magnesia, the carbon dioxide gas being obtained as a by-product. Magnesia is the basis of the magnesite bricks used largely for

[10] *Génie Civil*, No. 7, Vol. XXXVI., p. 107.

special requirement in the construction of metallurgical furnaces. Calcined magnesia is worth from \$15@\$19 per ton, while lime is worth about \$5. While magnesite occurs in many parts of California, but from 2,000 to 3,000 tons a year reaches the market from this source, owing to the cost of transportation. In 1900, 28,000 metric tons of magnesite was imported from Europe, some from Styria, but principally from Eubœa, Greece. Good Styrian magnesite contains from 90 to 95% $MgCO_3$, 1 to 2% SiO_2, 0·5 to 2% $CaCO_3$ and FeO up to 6%. The Eubœan magnesite averages 95 to 98% $MgCO_3$, and is generally free from iron oxide and silica. One hundred pounds of pure magnesium carbonate will yield 47·6 lb. MgO and 52·4 lb. CO_2, while the same amount of pure calcite will yield only 44% CO_2. In manufacturing liquid carbon dioxide from magnesite, the following method is used: The furnaces are circular in shape and mounted on columns. They are 10 ft. in diameter, 15 ft. high above the columns and have a total height of 23 or 24 ft. Inside the furnace and projecting a little from the masonry at top and bottom are seven vertical iron pipes, 12-in. inside diameter, and open at both ends. The magnesite, crushed to egg size, is charged in these pipes, their lower ends being previously hermetically plugged after charging; the pipes are closed at the top in a similar way. The furnace is heated with gas fuel (mineral oil burned in proper burners), inlets being supplied for the heating gases and outlets for the products of the combustion. The pipes are connected at their upper ends with a common 6-in. pipe which collects the carbon dioxide gas resulting from the calcination of the carbonate. The charging is made from a small wagon provided with a chute which circulates on a movable platform car allowing the different furnaces to be successively charged. One furnace is generally charged in the morning and the calcination proceeds for 20 hours, which is sufficient to expel practically all of the combined carbon dioxide. The stone when discharged from the retorts contains 95 to 96% MgO. If calcined at a comparatively low temperature the calcined product will absorb water and carbon dioxide after a few days, analyzing then only 94% MgO. The carbon dioxide gas as it leaves the retorts circulates through water-cooled coils, where its temperature is lowered and then passes to the gas holder of a capacity sufficient for 3,000 or 3,500 lb. of gaseous carbon dioxide (approximating 30,000 cu. ft.). From the gas holder the gas is purified and delivered to the compressors, which liquefy it and deliver it to the steel cylinders. Two men can fill 20 drums in an hour. There are many other arrangements used to calcine magnesite or other carbonates, but the method described above will suffice for the purpose of illustration.

The Development of the Liquefied Carbonic Acid Gas Industry.

United States.—(By J. C. Minor, Jr.)—There are 19 companies engaged in the liquefaction of carbonic acid gas in the United States and two in Canada, whose names and addresses are given in the table on the following page.

At six of these plants the gas is prepared directly from the natural carbonic acid gas arising from mineral springs. Eight of the plants obtain their gas from the fermentation of liquids, nine from the combustion of coke, and twelve from the decomposition of carbonates, either by heat or by wet processes.

Name of Company.	Address.
American Carbonate Co.	New York, N. Y.
American Carbonic Acid Gas Co.	San Francisco, Cal.
Bishop & Babcock Co.	Cleveland; New York; Chicago; St. Paul.
Crescent Chemical Co.	Brooklyn, N. Y.
Canadian Carbonate Co.	Quebec, Can.
Carbon-Dioxide & Magnesia Co.	Philadelphia, Pa.
Chicago Aëriform Co.	Chicago, Ill.
Hecla Compressed Gas Co.	Chelsea, Mass.
Lennox Chemical Co.	Cleveland, O.
Liquid Carbonic Acid Manufacturing Co.	Chicago; New York; Pittsburg; St. Louis; Milwaukee; Cincinnati; Baltimore; Minneapolis; Kansas City.
Liquid Carbonate Co.	Toronto, Ont., Can.
Merrimac Chemical Co.	Boston, Mass.
National Carbonic Acid Gas Co.	Buffalo, N. Y.
Western Carbonic Acid Gas Co.	San Francisco, Cal.
New York Carbonic Acid Gas Co.	Saratoga Springs, N. Y.
Geysers Natural Carbonic Acid Gas Co.	Saratoga Springs, N. Y.
Lincoln Spring Co.	Saratoga Springs, N. Y.
Saratoga Natural Carbonic Acid Gas Co.	Saratoga Springs, N. Y.
Saratoga Sprudel & Carbonic Acid Gas Co.	Saratoga Springs, N. Y.
Champion Natural Carbonic Acid Gas Co.	Saratoga Springs, N. Y.
Pratt Laboratory	Atlanta, Ga.

Saratoga Springs, N. Y., is the only place in the United States at which natural carbon dioxide gas is liquefied. For over a hundred years several carbonated saline springs have been flowing naturally to the surface under considerable pressure due to the contained gas, notably the High Rock and the Hathorn Springs. The volume of water and gas delivered through these natural crevices is quite small, but by drilling many springs to depths of between 100 and 600 ft. Saratoga has become most prominent as a watering place.

In geologic occurrence all of the springs are located along the line of a fault passing through the town from the northeast to the southwest. The wells are generally drilled 6 in. in diameter, and extend down and through the strata of the Hudson river shale until the Trenton limestone is reached. Wells that have been drilled through the limestone formation as far as the underlying Potsdam sandstone have always been weakened in force. About 20 springs in the village are used for drinking purposes, while those used for gas production, about 20 in number, also, are situated along the line of the fault 1·5 miles to the southwest. The latter are of greater output in gas and water than those in the village, the production being frequently aided by pumps. The average spring used for producing carbon dioxide gas will yield about 400 lb. of gas per 24 hours, with a flow of water from 5 to 6 gal. per minute. In a few cases the flow of the spring has been more than quadrupled by pumping. The gas is separated from the water at the mouth of the spring and is piped to the gas holder from which it is subsequently drawn off and purified by passing it through dryers and purifiers.

The natural carbon dioxide gas contains about 0·5% of air, a much less quantity than occurs in gas produced by other processes. A trace of hydrogen sulphide is frequently found, although several of the companies make no effort to remove this impurity.

It is obvious that the cost of manufacture of liquefied carbonic acid gas is less at Saratoga than by processes carried on elsewhere, but because of the geologic conditions, the supply of gas is limited and the local companies can hardly become a controlling factor in this industry. As late as 10 years ago, the ordinary price of carbon dioxide gas was about 20c. per pound, and even at this price its greater

convenience led to its rapid adoption, principally in the manufacture of carbonated beverages. The price is determined more by the length of time that the steel cylinders are kept by a customer than by any other factor. At the present time it ranges from 5 to 12c. per lb. with an average of about 7c. in the supply of all classes of trade.

The large consumer who prefers to make his own carbon dioxide gas rather than to purchase the liquefied product, and whose consumption may, roughly speaking, average 10,000 lb. a year, can manufacture gas from a carbonate for about 3·5c. per lb. including waste and labor.

It has been impossible to obtain exact figures of production, but the estimate for the United States and Canada during 1901 of 14,000 short tons of liquefied carbon dioxide gas is substantially correct. On the surface this does not indicate a very large industry, nor is it when measured by the amount of money invested. The total value of the cylinders owned in the United States by all the companies is estimated at $2,000,000. The magnitude of the field of operation is best shown however in the fact that the amount of gas manufactured in 1901 in the United States was sufficient to carbonate over 150,000,000 gal. of soda water, a use for which the greater part of the liquefied gas was consumed.

Germany.—The development of the liquid carbon dioxide industry has attained great prominence in Germany,[11] and 29 firms owning 39 carbon dioxide works have formed the Deutsche Kohlen Actien Gesellschaft. This does not include however the largest independent works, which alone supply the entire German demand.

The branch of the industry in Würtemburg threatens the manufacture of carbon dioxide gas from coke or lime as the natural gas wells up from the earth in the valley of Eyachthal on the upper Neckar, and can be collected at a nominal cost. One firm in this locality, with a capital of $500,000, possesses 30,000 steel drums, and to avoid freight on them extremely strong iron tank-wagons each of 10 tons' capacity are used to transport the liquid carbon dioxide in bulk to Zurich, Berlin and Vienna, where the steel drums are charged for local distribution. In 1898, 2,950 tons of liquid carbon dioxide valued at $150,000 were exported from Germany, and in 1900 the total reported production of the world amounted to 38,000 tons, distributed as follows:—

Countries.	Number of Works.	Production in Metric Tons.
Germany.....	42	16,000
France.....	15	7,000
Austria-Hungary.....	12	1,800
United States.....	18	14,000

In Germany this industry has increased very rapidly during the last 15 years, as shown by the following figures: Production in 1884 amounted to 122 metric tons; in 1891, 3,000 metric tons; in 1897, 11,000 metric tons; and in 1900, 16,000 metric tons. Of the last named amount, Berlin consumes no less than 1,800 tons, which corresponds to an annual consumption of 2 lb. of liquid carbon dioxide gas per capita of the population in this city. Two-thirds of the German works produce the liquefied product from the natural gas emanating from

[11] British Consular Reports, Nos. 561 and 2671, 1901.

springs. The remaining third employ chemical methods to generate the initial gas. The amount of capital invested in this industry in Germany is estimated at $5,000,000, and to this should be added the value of 700,000 steel drums and 30 steel tank-wagons, making in all, $9,000,000. Fifteen years ago the price of the liquid was about 25c. per lb.; now it has decreased to about 4c. per lb. The export from Germany of liquid carbon dioxide in 1890 amounted to 4,000 tons, valued at $1,500,000, which diminished to 3,618 tons in 1899.

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RECENT PROGRESS IN THE WETHERILL SYSTEM OF MAGNETIC SEPARATION.

By H. A. J. Wilkens.

The Wetherill system of magnetic separation has been so frequently described in the various technical publications that the principles upon which it is based, as well as the results obtained by its use, are fairly well known to the mining and metallurgical professions. Briefly stated, John Price Wetherill, the inventor of the system, was the first to realize the commercial possibilities of utilizing the slight magnetic qualities inherent in a large number of ores and minerals and to devise a practical machine to separate such materials by means of a highly condensed magnetic field.

Broad patents[1] covering the process as well as various types of machines were granted in the United States and are now owned by the Wetherill Separating Co., of New York, and similar patents were granted in many foreign countries, which are now under the control of a German syndicate represented by the Metallurgische Gesellschaft, of Frankfort-on-Main, Germany. The broad process patents have been sustained in the German courts, a suit for non-validity having been brought by the Mechernicher Bergwerk-Aktien Verein. From the decision of the German Reichs Gericht, which is printed in full in the *Engineering and Mining Journal,* November 17, 1900, the following extract shows the view taken by the Court:—

"The arguments in support of the decision are stated as follows: 'For the consideration of the question, whether the process characterized by the first claim was new and patentable at the time of the application, it is immaterial that long before the date of application the existence of weakly magnetic and non-magnetic minerals was known, besides the strongly magnetic ores; likewise the classification given by M. Faraday, 60 years ago dividing all substances into two classes, paramagnetic and diamagnetic, since constituting a common acquisition of scientific and technical knowledge, is by no means prejudicial to the patent.

" 'The Application Department knowing these premises has allowed the first claim on the well-justified ground that Wetherill was the first to recognize the applicability of these known facts to the magnetic separation of weakly magnetic substances, without first transforming them into the strongly magnetic state

[1] United States Patents No. 555,792 and No. 555,794, March 3, 1896.

and to demonstrate their separation from non-magnetic substances upon a commercial scale.' "

Apparatus.—The machines devised by Mr. Wetherill have passed through a period of evolution, the original ones having been gradually superseded by others which, although operating on the same general principle show considerable improvement in their mechanical features. The main credit for the improvements is due to Mr. Lewis G. Rowand, who has been connected with the Wetherill process in this country almost since its inception, and to Mr. Max Schiechel, who has charge of the operations of the company exploiting the foreign patents.

In general the machines used can be divided into two types:—

1. Separators in which the magnetic particles are lifted away from the raw material brought to the magnets, and mechanically carried away from the non-magnetic products, and—

2. Separators in which the course of the moving ore is influenced magnetically

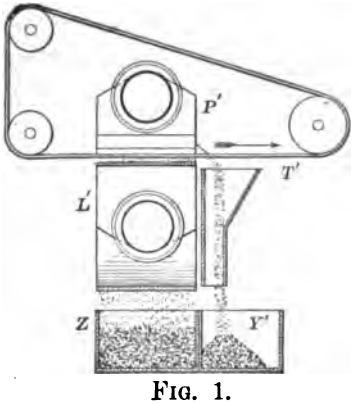

FIG. 1.

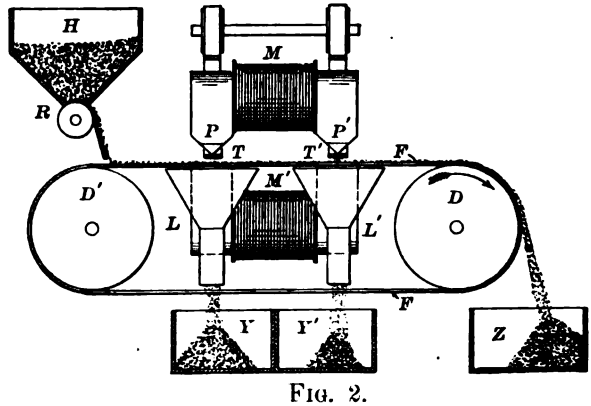

FIG. 2.

MAGNETIC SEPARATORS OF THE FIRST TYPE.

in such a way as to carry the various ingredients in separate directions, according to their magnetic permeability.

The most highly developed machine of the first class is illustrated in Figs. 1 and 2, the former showing the general principle of the operation, and the latter a complete working machine with an 18-ft. feed-belt and three pairs of magnets. Referring to Fig. 1; *M* and *M'* are two magnets so arranged that the pointed poles *P*, *P*¹ of the upper magnet are placed close to and above the flat pole pieces *L* and *L*¹ of the lower magnet. Passing through the magnetic field produced between these pole points is a rubber feed-belt *F*, which is carried by the pulleys *D* and *D*¹ and receives the continuous feed of ore from the hopper *H* by means of the feed-roll *R*. The two take-off belts *T* and *T*¹ move at right angles to the feed-belts along the bottom of the upper pole points.

The machine operates as follows: As soon as the material on the feed-belt *F* arrives below the pole point *P*, the magnetic materials in the mixture are lifted to this point and are held against the lower side of the take-off belt *T*, which carries them along the pole point until they are removed from the field and dropped through a suitable chute into a receptacle *Y*. Meanwhile the material

remaining on the feed-belt has been brought to the second pole point P^1 of the magnet M where the operation is repeated and the remaining magnetic materials are removed from the field and dropped through suitable chutes into receptacle Y^1. The non-magnetic products are finally carried by the feed-belt F into the receptacle Z. In practice it is often found advisable to make a series of magnetic products, and machines have been built of this type with two or three pairs of magnets placed in series across the same feed-belt. As a rule these pairs of magnets are made of gradually increasing strength or the strength of the successive magnetic fields is increased by the amount of current passed through the magnetic coils or by gradually decreasing the distance between the upper and lower pole point. On the three-pair magnetic machine, six magnetic products and one non-magnetic product will be produced in this manner, each succeeding

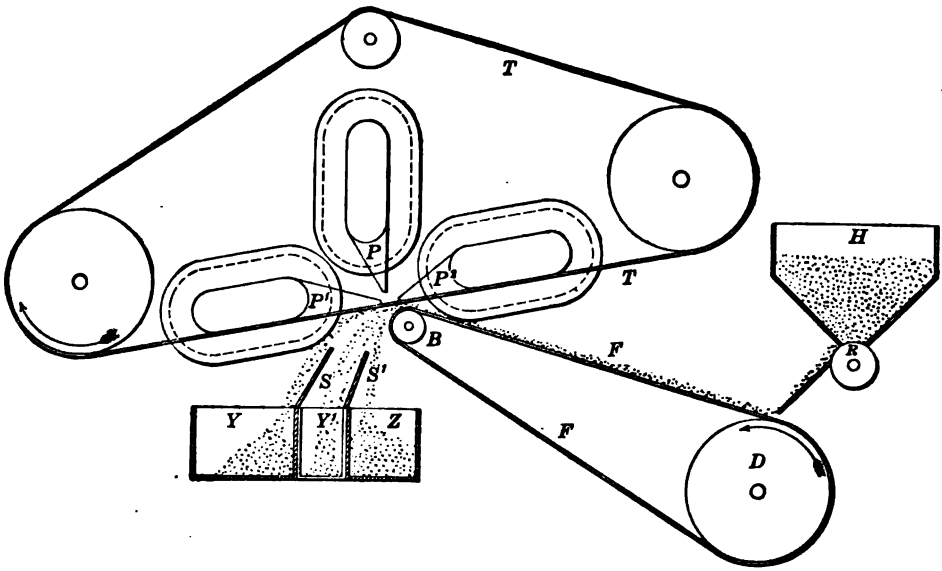

FIG. 3.—MAGNETIC SEPARATOR OF THE SECOND TYPE.

magnetic product being composed of material of a somewhat slighter magnetic permeability than the preceding one.

Fig. 3 shows a machine used in Europe and in Australia for ores which are very slightly magnetic. In this are three magnetic coils and pole pieces. The pole point P, which does the active work of separation, is of opposite polarity to the points P^1 and P^2. Around the pole point P and actuated by the pulley D is a thin linen belt F on which the ore is fed from the hopper H by means of the feed roller R. When the material reaches the pole point P, the magnetic particles adhere to the feed-belt F as it rounds the point, while the non-magnetic materials are thrown off by the momentum imparted to them by the moving belt. By means of the shutter S, which can be adjusted with a small set-screw, the two grades of ore are accurately separated. This machine operates successfully on materials of very slight magnetic permeability at the expense of a comparatively low magnetic current, it being only necessary to hold the material for a moment

against the pole point as compared with the necessity of actually lifting the materials in machines of the type shown in Fig. 1. There is some wear of the feed-belt while rounding the pole point *P*, as well as that of the pole point itself. The proper adjustment of the shutter *S* as well as that of the whole machine, is a somewhat delicate matter, and its use is advisable only when the ore is so slightly magnetic that it is impossible to make satisfactory separation with the machine shown in Fig. 1.

Fig. 4 shows another type of machine which has been used to a considerable

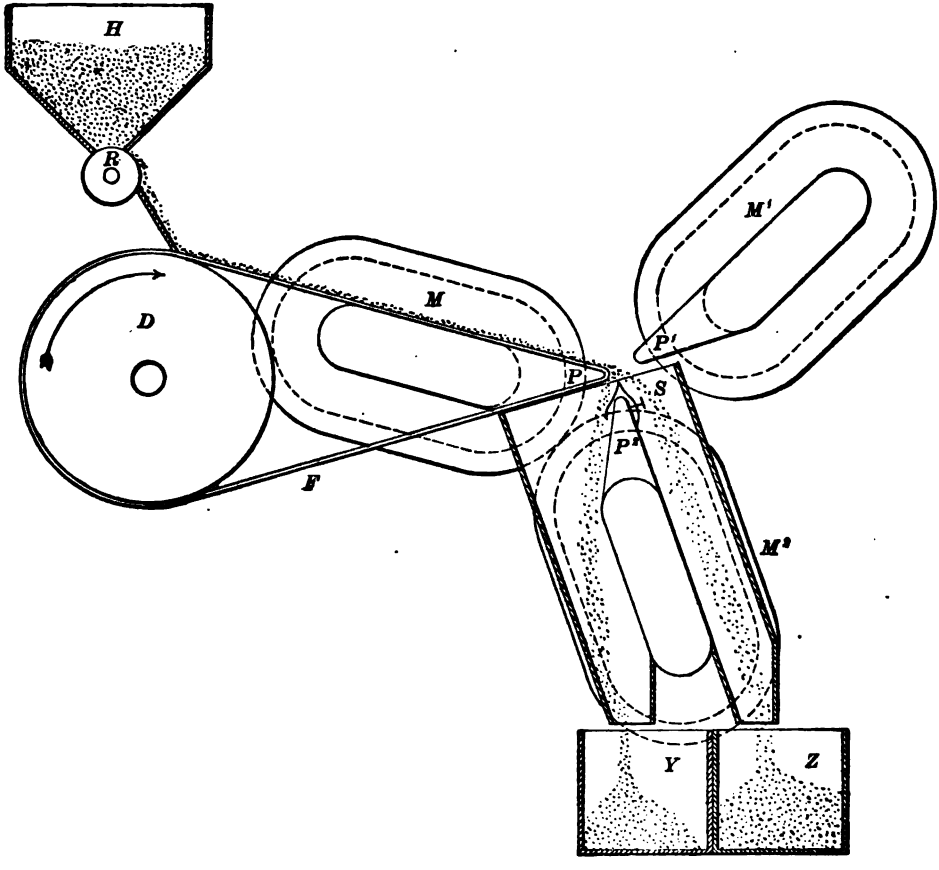

FIG. 4.—MAGNETIC SEPARATOR OF THE COMBINED TYPES.

extent abroad, combining to some extent the principles of the two machines already described. There are three magnets and pole points consisting of the main pole *P* and the secondary poles P^1 and P^2. The latter poles being of opposite polarity to the former. Below and around these pole points is the take-off belt *T* passing in the direction indicated by the arrow. The operation of the machine is as follows: The ore from the hopper *H* is fed by means of the roller *R* upon the feed-belt *F*, which is actuated by means of the pulley *D* and is supported at the upper end by a small brass roller *B*. As the ore reaches the magnetic field,

the non-magnetic material is dropped into the receptacle Z being separated from the magnetic material by the shutter S^1. The magnetic particles are carried beyond the shutter S^1 in a horizontal direction and fall into the receptacle Y or Y^1, according to their magnetic permeability. In operation the take-off belt T is needed more to keep the pole points clean than to hold and carry the ore.

The machine illustrated in Figs. 1 and 2 is being used exclusively in the United States. Although its first cost is considerable on account of the high power magnets employed and the strong frame and running gear, experience under varying conditions has shown that it is warranted, as continuous running and a minimum expenditure for repairs is guaranteed. The standard type placed upon the market by the Wetherill Separating Co. is operated with an 18-in. feed-belt and with from one to three pairs of magnets which are wound as a rule with 30,000, 60,000, and 100,000 ampere turns. The current employed is 110 volts and for a three-pair magnet machine the maximum amperage for the magnets is respectively 5, 15, and 30. The power necessary to actuate the running parts of the machine does not exceed 0·5 H.P. The power necessary to produce the current for the magnets varies from 1 to 7 H.P., depending entirely upon the magnetic permeability of the ore which is separated and the number of pairs of magnets on the machine. The capacity of the machine varies from 0·3 ton to 6 tons per hour, and is estimated by the size and magnetic permeability of the material treated. It is greatest on coarse sizes of more highly magnetic material and least on fine sizes which are very slightly magnetic.

Applications.—In general it may be stated that all minerals containing iron or manganese are susceptible to separation by the Wetherill process. The magnetic qualities of minerals of this character, however, are not directly proportionate to the quantity of these elements contained, but seem to depend more upon their combination. It is a curious fact that almost all dolomite and even limestone, which is found adjacent to ore bodies and which may contain barely a trace of iron or manganese, will be magnetic, while pure iron pyrite, FeS_2, appears to show no paramagnetic properties whatever. On the other hand, there are some of the rarer metals, as chromium and cerium, which show sufficient magnetic properties to enable ores containing large quantities of them to be handled on the Wetherill machines. To the presence of cerium in monazite must be attributed the ability to separate this ore from quartz and other non-magnetic materials. It has been found also that minerals from different localities, although of practically the same chemical composition, will vary in their magnetic attractability, so that in most cases an actual experimental treatment is necessary in order to determine whether an ore can be successfully treated by the Wetherill process or not. Thus, a few zinc blendes, more especially those of the darker varieties, will be comparatively highly magnetic, while others are very much less so and may not be susceptible to magnetic treatment.

Apart from the magnetic qualities of the minerals, the successful treatment of an ore by the Wetherill system is predicated upon the same general conditions which govern mechanical separation in that the ore must be crushed sufficiently fine to bring about a breaking apart of the separate ingredients. It is practically impossible to treat some ores on account of the extremely fine dissemination of

the ingredients. The treatment of dust is impracticable magnetically for the same reasons which have rendered it impossible to treat fine slimes either by water or air separation. When the particles become so small in size that the effect of gravity is *nil*, a satisfactory treatment either in air or in water becomes impossible, and despite the claims of various inventors and manufacturers I have as yet failed to find a concentrating machine which will successfully treat material below 300-mesh size either in air or water.

Sizing is as advantageous in the Wetherill process as it is in all other methods of mechanical separation. Various devices have been designed and operated for utilizing a highly condensed magnetic field for separating ore in water, but the scope of magnetic separation is apparently confined to the treatment of dry material. A dry treatment presents advantages in crushing and sizing, although the dust originating in dry mills is at times a decided disadvantage and as most ores from the mines must previously be passed through a dryer, the cost of treatment is thereby increased.

The Wetherill machines in the United States handle ore with a maximum coarseness of 8-mesh, and, while it is rare that minerals are so coarsely disseminated as to warrant crushing to larger size, the Wetherill principle can be readily adapted for material as coarse as 0·5-mesh.

The following list is composed of some of the combinations of minerals which have been successfully treated by the Wetherill process. In most cases two or three magnetic products consisting of different minerals are made. A large number of the minerals which it has been possible to separate magnetically are so similar in specific gravity that their separation by gravity machines is impossible. In this list the magnetic minerals of each combination are given in the order of their permeability, the product mentioned last being in each case the non-magnetic tails. A few minerals, as zinc blende, for instance, occur sometimes as the magnetic and sometimes as the non-magnetic portion, due to the variation of the magnetic permeability. Resin blende is non-magnetic, while some of the black blendes are quite highly so. In other instances the associated mineral is more magnetic, as is the case with spathic iron and blende; the former being withdrawn, while the latter is left as non-magnetic tails, even though it possesses magnetic permeability.

Separated Minerals.	Non-Magnetic Tails.	Separated Minerals.	Non-Magnetic Tails.
Franklinite		Spinel	Corundum.
Tephroite		Pyrrhotite, hornblende	Chalcopyrite.
Fowlerite		Garnet, olivine } Blue ground }	Diamonds, etc.
Garnet	Willemite.	Hornblende	Apatite.
Zinc blende	Chalcopyrite.	Rutile (irony varieties)	Apatite.
Zinc blende	Iron pyrite.	Menaccanite	Rutile.
Zinc blende	Galena.	Tetrahedrite	Gangue.
Zinc blende	Barite.	Bornite	Gangue.
Spathic iron	Zinc blende.	Malachite, azurite	Gangue.
Spathic iron	Copper pyrite.	Manganite, rhodonite	Gangue.
Spathic iron	Cryolite.	Limonite	Calamine.
Dolomite	Galena.	Limonite	Gangue.
Menaccanite, garnet, monazite	Quartz.	Hematite	Gangue.
Wolframite	Cassiterite.	Spathic iron ore	Gangue.
Wolframite	Quartz.		
Garnet	Corundum.		

The following results obtained by the Wetherill system of magnetic separation have been selected at random from several thousand tests made on various ores.

Copper Ore from Mexico.—This ore was a product from a wet cencentrating mill, and consisted of copper pyrite, bornite and garnet containing 6·3% Cu. The separation gave 70% of garnet, containing 0·3% Cu, and 30% of a copper product containing 19·8% Cu, representing a yield in copper of 96·6%.

Spathic Iron and Zinc Blende from the Siegerland, Germany.—This material was a by-product of the wet concentrating mills, and consisted of a mixture of spathic iron ore and zinc blende, the original ore assaying 20% Zn. The magnetic separation gave 68·4% of spathic iron with 5·45% Zn, 31·6% of zinc blende with 53·46% Zn, representing a yield in zinc of 82%.

Tin Ore from Spain.—This material was produced by a wet separation, and contained about 48·5% Sn and 22·5% WO_3, the latter being present as wolframite. The following results were obtained: 30·7% of wolframite, containing 0·8% Sn and 73·2% WO_3; 68-5% of tin ore, containing 70·5% Sn and 1·1% WO_3, representing a yield in wolframite of 97% and a yield in tin of 98·5%.

Spanish Copper Ore.—This ore consisted of copper glance, malachite, and azurite, with a dolomite gangue, and averaged 2·9% Cu. The following products were obtained: 12·6% of copper ore, containing 17·2% Cu; 85·4% of gangue, containing 0·75% Cu, representing a yield of 75·5% of the copper in the raw material.

Australian Tailings.—This raw material was a by-product in the wet concentration of the Broken Hill sulphide ores, and assayed 30·08% Zn, 8·68% Pb, and 10·09 oz. Ag. The following products were obtained: 26% of a garnet product, containing 10% Zn, 2·9% Pb, and 5·48 oz. silver per ton; 54·5% of a zinc product containing 48·1% Zn, 6·7% Pb, and 12·58 oz. silver per ton; 19·5% in weight of a lead-quartz product, containing 8·6% Zn, 22% Pb, and 14·52 oz. silver per ton; a concentration representing a zinc yield of 89·2%.

The Wetherill process and machines are in commercial operation at the following foreign plants: In Germany, at the Gesellschaft des Emser-Blei & Silberwerks, Ems; the Bensberg Gladbacher Bergwerks & Huetten-Actien-Gesellschaft "Berzelius" Gladbach; the Silber & Bleibergwerk "Friedrichssegen," Friedrichssegen a/Lahn; and the Gewerkschaften Lohmannsfeld & Peterszeche, Duesseldorf, Lohmannsfeld, Neunkirchen, Rbs. Arnsberg. The operations are confined to the separation of spathic iron and zinc blende. Previous to the introduction of the Wetherill process the ores at these plants were roasted in order to change the iron carbonate to magnetic iron oxide, which was afterward removed by some of the older forms of magnetic separators. The direct treatment of this ore has not only proved cheaper on account of avoiding the cost of roasting, but the resultant products have also been of much higher grade. At the Actien-Gesellschaft fuer Zink-Industrie, Hamborn, Rheinland, the Wetherill process is used for separating a mixture of pyrite and blende; the ore is roasted before being treated on the machines, the roasted pyrite being the product removed magnetically.

In Denmark, at Copenhagen, the Oresunds Chemiske Fabriker has several machines installed for the separation of cryolite, spathic iron and copper pyrite, the latter two being magnetically removed from the former.

In Belgium, at Hoboken, Anvers, the Usine de Desargentation is a plant which has been employed mainly for the separation of wolframite and tin ore and in the removal of monazite from titanic iron and quartz.

In Russia, at St. Petersburg, the Actien-Gesellschaft Stal is operating on iron ore.

In South Africa, at Kimberley, at the De Beers Consolidated Mine, Ltd., a machine of the American type is employed for removing the garnet, olivine and other heavy ingredients from the diamonds in the concentrates from the washers.

In Australia, at Melbourne, the Australian Metal Co. has 55 machines installed for the separation of the Broken Hill sulphide ores separating both garnet and blende from galena and quartz.

The testing and experimental station for foreign countries is located at the Maschinenban-Anstalt Humboldt, Kalk, near Cologne, Germany. At this plant various types of Wetherill machines are installed as well as apparatus for crushing, screening, water and air separation, etc., which might be used to advantage in connection with the Wetherill process.

Aside from the locations mentioned above, there are a number of plants in foreign countries in course of construction for the separation of pyritic blende, tin ore, etc.

In the United States the largest application of the Wetherill process has been in connection with the separation of the Franklinite ores in Sussex County, N. J. At Franklin Furnace, N. J., are two plants having capacities of 500 tons and 1,600 tons per day respectively; the former is not in operation at present. The larger plant has handled as much as 900 tons in 12 hours over 17 machines of the Rowand type each equipped with three pairs of magnets. The cost of treating raw material has been as low as 38c. per ton in the most favorable month of 1901, including crushing, sizing, cooling, magnetic separation, jigging of the non-magnetic tails, drying of the jigged concentrates, and loading them on cars for shipment. The general scheme of the separation has been described at some length by Mr. John Price Wetherill,[2] although since this was written the methods of crushing and handling the material and the type of the magnetic separators have been largely improved. In all about 180,000 tons of ore were treated magnetically by the Wetherill process at Franklin Furnace during the year 1901.

At the Pride of the West mine, Washington Camp, Ariz., six magnetic separators of the Rowand type have been in operation on a mixture of copper pyrite, zinc blende, galena, garnet and quartz. Four of the separators remove roasted copper pyrite from a mixture of blende, garnet, galena, etc., and two of them which are of higher magnetic power are used for treating the non-magnetic tails from the above operation, removing magnetically garnet first and then zinc blende, the latter on account of a very slight admixture of iron being sufficiently magnetic to be removed in the powerful field of the machine. The galena is subsequently separated from the non-magnetic mixture of galena, quartz, limestone and calcite by means of Wilfley tables.

At the Warren mine, Warren, N. H., the process has been in operation since

[2] *Engineering and Mining Journal*, July 17, 1897.

1900 on ores of complex nature carrying galena, zinc blende, copper pyrite, pyrrhotite, pyrite and quartz. The ore is first concentrated on jigs to remove as much of the gangue as possible; it is then slightly roasted and passed over the magnetic separator, which gives the following products: First, magnetic heads consisting of pyrrhotite and oxidized pyrite; second, oxidized copper pyrite; third, zinc blende assaying from 55 to 56% zinc. The non-magnetic tails consisting of galena and quartz are subsequently separated by dry jigging.

At the mines of Witherbee, Sherman & Co., at Mineville, N. Y., the Wetherill magnetic process is used for separating apatite and hornblende, this product being the tails from the Wenstroem machines, which concentrate the magnetite ore. At present but one machine of the Rowand type is installed, several others, however, will be in operation shortly to handle the increased output of the main separating plant.

The Corundum Mining & Manufacturing Co., of Tree, Ga., will use the Wetherill process for the separation of garnet from corundum, which is produced by the wet concentration of the corundum-bearing granite.

The Colorado Zinc Co. uses the Wetherill process for separating zinc blende from pyrite at its plant in Denver, Colo. One of its main sources of supply is ore from the White Quail group of mines at Kokomo, Colo., which consists of gold-bearing pyrite with an admixture of zinc blende and a small amount of galena. This ore is first concentrated on Wilfley tables, producing a lead-iron concentrate and tails consisting of pyrite and zinc blende, the latter is dried and passed over Wetherill machines to remove magnetically the raw blende.

A similar plant is operated by Wilfley & Byron at Kokomo, Colo., for the treatment of ores of the same character.

The Empire Zinc Co., of Colo., has installed a Wetherill machine of the Rowand type at its plant at Cañon City, to treat miscellaneous ores either raw or after roasting, for the separation of zinc blende from galena and pyrite.

Messrs. Hulss & Kithil are installing a plant at Ellenboro, N. C., for the purpose of cleaning monazite sand, which is produced in the sluicing operations and consists of menaccanite, garnet, monazite, quartz and other gangue. The materials are removed by the Wetherill machines in the order stated above, the quartz remaining as the non-magnetic ingredient.

The main testing plant of the Wetherill Separating Co. is located at the corner of Ferguson and Clover Streets, Newark, N. J., and is equipped with appliances for testing any quantity of ore.

There are smaller machines installed for testing ores at the laboratories and testing plants of Henry E. Wood, Denver, Colo.; The Kootenay Ore Co., Ltd., Kaslo, B. C.; the School of Mines, Kingston, Ont.; the School of Mines, McGill University, Montreal, and the United States Geological Survey, Washington, D. C.

GENERAL SUMMARY OF THE IMPORT DUTIES OF THE PRINCIPAL COUNTRIES IN THE WORLD.

Substance.	Austria Hungary. 100 kg. or ad. val.	Canada Ad. val. Tons and lb.	Chile. Ad. val.	China. 133⅓ lb.	France. 100 kg.	Germany. 100 kg.	Italy. 100 kg.	Japan. 133⅓ lb. ad. val. Tons.	Mexico. Kg.	Russia. 36.1121b	Spain. 100 kg.	Sweden 100 kg.	United States. Ad. val. Tons and lb.
	$	$	$	$	$	$	$	$	$ Mex.	$	Pesetas	$	$
Alum	0·609	Free.	5%	0·0815	0·965	0·714	0·193	0·099	0·25	.....	1·80	0·335	0·005 lb.
Aluminum, crude	Free.	Free.	Free.	.....	38·60	Free.	0·97	Free.	0·25	1·93	2·00	Free.	0·08 lb.
M'f'res.	.....	(1)25%	25%	.....	38·60	14·28	19·30	.....	0·25	2·393	48·75	.....	45%
Antim'ny, ore	Free.	Free.	Free.	.....	Free.	Free.	Free.	Free.	Free.	0·15	0·30	Free.	Free.
Metal	Free.	Free.	25%	.....	1·158	.....	1·16	5%	0·25	0·23	2·00	Free.	0·0075 lb
Arsenic	0·203	Free.	25%	0·815	Free.	.....	0·193	.....	0·25	0·41	12·00	Free.	Free.
Arsenious acid	0·203	Free.	.....	0·815	.....	.....	.....	.....	.....	0·41	.....	.....	Free.
Asbestos, crude	Free.	Free.	5%	.....	.....	Free.	.....	.....	0·01	0·10	.....	Free.	Free.
M'f'res.	(2)	30%	5%	.....	.....	(3)	.....	10%	.....	0·46	.....	Free.	25%
Asphalt	Free.	Free.	Free.	.....	Free.	Free.	0·10	.....	0·04	(4)0·077	0·60	Free.	3·00 t.
Barytes	.....	.....	Free.	.....	.....	Free.	0·39	.....	.....	.....	.....	.....	0·75 t.
Borax, crude	.....	Free.	25%	.....	Free.	Free.	0·10	0·619	.....	0·62	12·00	.....	0·05 lb.
Refined	1·218	Fr e.	25%	.....	1·93	Free.	0·10	0·619	.....	0·93	12·00	.....	0·05 lb.
Cement	1·218	(a)0·125	5%	5%	(5)0·096	.....	0·10	.....	(b)0·50	0·10	.....	0·161	(a)0·08
Coal	Free.	(6)Free.	Free.	0·126	.....	Free.	Free.	0·44 t.	Free.	.....	3·00	.....	(6) Free.
Coke	Free.	.....	25%	0·105	0·023	Free.	Free.	0·395 t.	Free.	.....	3·00	.....	30%
Copper, pigs, ingots	Free.	Free.	Free.	0·70	Free.	Free.	0·77	5%	0·10	1·828	(7)	Free.	Free.
Bars, sheets	(8)3·25	Free.	Free.	1·35	2·509	2·856	2·70	1·54	(9)0·12	2·39	(7)	1·34	0·25
Wire	(8)3·25	15%	Free.	.....	2·509	2·856	3·86	3·75	0·20	.....	48·00	2·68	45%
Copper sulphate	Free.	Free.	(10)15%	.....	0·772	.....	0·39	.....	.....	0·772	1·20	10%	0·005 lb.
Copperas	.....	Free.	Free.	0·07	0·193	.....	0·39	.....	.....	0·17	1·80	10%	0·0025 lb
Fluorspar	Free.	.....	Free.	.....	.....	Free.	Free.	.....	.....	.....	.....	.....	.....
Graphite, crude	Free.	10%	Free.	.....	Free.	.....	Free.	.....	0·08	.....	.....	Free.	Free.
M'f'res.	0·406	25%	25%	.....	.....	.....	.....	.....	.....	.....	.....	.....	Free.
Hydrochloric acid	0·203	20%	25%	.....	0·071	.....	0·193	.....	.....	0·343	2·60	Free.	35%
Iron, pig	0·325	2·50 t.	Free.	0·03	0·386	(11)0·238	0·58	0·042	0·01	0·289	2·40	Free.	4·00 t.
Bars	1·117	7·00 t.	Free.	0·037	0·965	0·595	(12)1·16	(13)0·178	.....	.....	11·40	0·67	0·006 lb.
Sheets and plates	(14)1·624	.....	Free.	0·087	(14)1·447	0·714	1·74	0·197	0·04	.....	(15)15·60	(16)1·07	.....
Steel, ingots	1·116	2·00	Free.	0·175	0·965	0·595	0·58	0·042	(b)0·50	0·417	6·00	0·54	(17)
Rails	1·116	30%	Free.	0·175	1·351	0·595	1·16	0·149	Free.	0·463	7·20	Free.	0·0035 lb
Tin plates	1·624	Free.	Free.	0·28	(18)2·89	1·19	(19)2·70	0·346	(20)0·01	1·312	24·00	Free.	0·015 lb.
Lead in pigs	0·812	15%	Free.	0·175	(21)0·77	Free.	0·10	0·184	0·05	0·077	2·00	Free.	0·02½ lb
Sheets, pipes wire	2·030	35%	Free.	0·395	1·35	0·713	0·58	9·38	0·05	0·232	2·00	Free.	0·025 lb.
Mangan. ore	Free.	Free.	Free.	.....	Free.	Free.	Free.	.....	.....	0·054	0·30	Free.	(22)Free
Nickel, crude	Free.	(23)10%	25%	.....	Free.	.....	Free.	1·705	0·25	1·828	2·00	.....	0·06 lb.
Bars, sheets	.....	Free.	25%	5%	2·509	.....	1·93	1·765	.....	2·393	2·00	.....	0.06 lb.
Petroleum, crude	1·42	(c)0·025	Free.	Free.	(d)1·737	1·428	1·54	.....	0·02	0·154	25·00	Free.	Free.
Refined	2·03	(c)0·05	25%	Free.	(d)1·93	1·428	9·26	(c)0 008	0·01	0·772	40·00	Free.	Free.
Pyrites	Free.	.....	Free.	.....	Free.	Free.	Free.	.....	.....	0·008	.....	Free.	Free.
Quicksilver	Free.	Free.	Free.	1·40	Free.	Free.	1·93	2·84	Free.	1·853	2·00	Free.	0·07 lb.
Salts	(24)0·34	(25)0·075	(26)0·036	Prohib.	(27)0·46	.....	Prohib.	.....	0·02	.....	3·90	Free.	(28)0·12
Slate, roofing	0·41	25%	Free.	Free.	0·266	0·12	.....	.....	0·01	0·077	.....	.....	20%
Soda	0·325	Free.	25%	.....	(29)0·44	(29)0·36	0·10	.....	0·03	0·415	4·55	Free.	0·002 lb.
Nitrate	.....	Free.	25%	.....	Free.	.....	(29)Free	0·24	0·01	Free.	1·20	.....	Free.
Sulphur	Free.	Free.	25%	(24)	(30)Free	.....	Free.	.....	0·01	0·015	1·50	Free.	(30)Free
Sulph'ric acid	0·304	25%	25%	.....	Free.	.....	0·10	.....	.....	0·17	2·60	0·14	(31)Free
Tin in blocks or pigs	Free.	Free.	Free.	0·875	Free.	Free.	Free.	0·996	0·12	0·348	15·00	Free.	Free.
Bars, plates, sheets	2·03	Free.	Free.	.....	1·158	1·428	2·90	.....	0·25	.....	.....	.....	.....
Zinc, blocks, pigs	0·406	Free.	Free.	0·175	Free.	Free.	Free.	5%	0·01	0·386	6.00	Free.	0·015 lb.
Sheets and plates	1·218	Free.	Free.	.....	0·772	0·714	0·77	10%	0·07	0·772	18·00	Free.	0·02 lb.
M'f'res	2·03	25%	35%	.....	2·316	(40)1·43	2·32	.....	0·25	.....	33·80	.....	.....
Zinc white	1·218	5%	25%	.....	5%	4·76	0·97	0·615	.....	0·463	.....	.....	0·01 lb.

NOTE.—The United Kingdom exacts no import duties on the above substances.
(a) Per 100 lb. (b) Per 100 kg. (c) Per gallon. (d) Per hectoliter. (1) Hollow-ware, 30%. (2) Paper, unformed, $2·08 per 100 kg.; paper, formed, $4·872 per 100 kg. (3) Yarn, string and cordage, $5·712 per 100 kg.; tissue, $9·52 per 100 kg.; other articles, $14·28 per 100 kg. (4) Crude only. Ground asphalt, $0·1108. (5) Portland cement, $0·1447. (6) Anthracite only. Bituminous coal, $0·53 per ton in Canada and $0·67 per long ton in the United States. (7) Copper of first fusion, 15·00 pes.; in bars and ingots, 27·00 pes.; in sheets and rails, 42·00 pes. per 100 k. (8) Plates, sheets and wires less than 5 mm. in section, $4·06 per 100 kg. (9) Bars only. Copper sheets and plates, $0·15 per kg. (10) Unrefined. (11 Iron for purpose of being wrought, $0·595 per 100 k. (12) Rods, plates and bars more than 7 mm. in section. Material 5·7 mm. in section, $1·35; less than 5 mm., $1·74. (13) Bars and rods more than 0·25 in. in section. Bars and rods 0·25 in. or less in section, $0·833. (14) Sheets more than 1 mm. thick. (15) Plates more than 3 mm. thick, 12·85 pes. (16) Plates more than 3 mm. thick, $0·804. (17) Duty varies from $0·003 to $0·047 per lb. (18) Plates less than 6 mm. thick. (19) Plates more than 1·5mm. thick. (20) Plates more than 55 cm. in length or 40 cm. in breadth, $0·07. (21) Containing less than 25 g. silver per 100 kg. (22) Less than 50% Mn, $0·40 per ton. (23) Nickel anodes. (24) Can be imported only by special permission. (25) Duty per 100 lb. in package. Salt in bulk pays $0·05 per 100 lb. (26) Duty per kg. of refined salt. (27) Crude salt. Refined salt pays $0·5848 per 100 kg. (28) Per 100 lb. salt in package. Salt in bulk pays $0·08 per 100 lb. (29) Crude soda. (30) Unrefined. (31) Not exceeding 1·38 sp. gr. (32) Coarse wares.

THE MINING STOCK EXCHANGES IN 1901.

THE tables on the following pages give a résumé of the business done during the past year on the leading exchanges of the United States and Europe. On the whole the year's record was a good one, although a general tendency toward lower values was in evidence, which may be regarded as a logical consequence of the inflated and fictitious quotations that ruled for many stocks in 1900.

THE BOSTON MINING STOCK MARKET IN 1901.

The formation of the Amalgamated Copper Co., which absorbed the Boston & Montana and Butte & Boston mines, has detracted largely from the prestige once held by Boston as a center of copper mining speculation. While Amalgamated stock is still dealt in to a large extent there, the offices of the company and the financial management are located in New York, which is now the speculative center.

The most prominent feature in regard to the year's quotations was the decline in the shares of the leading mining companies. An average for the year shows a falling off of about $50 from the top prices, which in the aggregate represents a loss of about $250,000,000. Nearly one-half of this amount was represented by the depreciation in Amalgamated shares, the remainder being contributed by other companies mostly engaged in copper mining. Calumet & Hecla fell as low as $535, a decline of $325 from the highest quotation. It is probable that many of the new mining companies which were floated during the copper "boom" will have to close down in the near future if the low prices for copper should continue.

THE COLORADO SPRINGS MINING STOCK MARKET IN 1901.

The value of the shares dealt in during 1901 was about $20,400,000. The records show important fluctuations in some of the leading stocks, such as Portland, Elkton, Isabella, and Jack Pot, in which a downward trend was noticeable. Portland fluctuated from $3·50 in January to $2·75 in December, and Elkton sold off from $1·90 at the opening of the year to $1·39 in December. Isabella varied between $0·77 and $0·34. The shares of El Paso and a few others were stronger in the latter part of the year than in the opening months.

FLUCTUATIONS IN MINING STOCKS AT BOSTON DURING 1901.

Name of Company.	Par Value.	January.		February.		March.		April.		May.		June.	
		H.	L.	H.	L.	H.	L.	H.	L.	H.	L.	H.	L.
Copper:													
Adventure Con. (b)	$25	$11·00	$9·75	$16·00	$10·00	$15·75	$12·50	$18·50	$14·25	$19·50	$14·00	$22·25	$17·00
Allouez (b)	25	3·50	2·50	4·00	2·63	3·75	2·50	3·00	2·75	3·50	2·50	3·00	2·50
Amalgamated (a)	100	95·50	88·00	95·00	88·25	108·63	94·00	128·50	99·75	124·25	108·00	127·00	119·00
Anaconda (a)	25	45·50	42·00	46·75	43·00	49·50	42·25	53·00	46·63	52·00	39·00	51·25	48·00
Arcadian (b)	25	19·50	16·50	20·50	15·50	24·75	17·50	23·00	20·00	21·50	15·50	19·00	16·00
Arnold (b)	25	5·00	3·75	4·25	3·50	5·75	3·50	5·00	3·50	3·75	2·50	3·00	2·00
Ash Bed (b)	25	·50	·30	·50	·36	·50	43·75	.....	.....	.....	.....	·35	·35
Atlantic (b)	25	29·00	26·00	35·00	25·50	35·25	32·00	35·00	30·00	35·00	29·00	38·50	30·00
Baltic (b)	25	35·50	32·50	45·00	34·00	47·50	38·25	49·88	41·00	52·00	35·00	54·00	42·75
Bingham (h)	10	16·88	15·00	22·75	16·00	26·50	20·75	29·50	23·50	26·50	20·00	24·25	22·00
Boston & Mont. (a)	25	325·00	308·00	331·00	312·00	370·00	330·00	450·00	350·00	484·00	395·00	498·00	438·00
British Columbia, Ltd. (d)	5	23.25	22·00	22·00	19·50	21·63	19·75	20·50	14·50	19·00	16·00	.....	.....
Butte & Boston (a)	10	83·00	77·00	87·00	78·50	106·00	85·50	119·00	95·00	116·00	92·00	124·50	112·00
Calumet & Hecla (b)	25	848·00	830·00	855·00	842·00	860·00	790·00	888·00	820·00	840·00	820·00	825·00	785·00
Centennial (b)	25	25·12	21·00	28·00	22·50	29·00	24·63	32·00	25·00	34·25	26·00	32·00	28·75
Copper Range (b)	25	38·00	34·00	50·00	37·50	58·00	44·00	60·00	49·50	64·00	46·00	75·88	51·50
Elm River (b)	12	6·00	4·50	6·63	4·50	7·00	5·00	6·88	5·25	5·50	4·00	5·00	4·00
Franklin (b)	25	18·50	16·00	24·88	16·75	25·12	21·00	23·00	18·00	19·50	16·00	18·00	16·50
Humboldt (b)	25	·50	·25	·75	·36	·63	·50	·50	·50	·35	·25	·25	·25
Isle Royale (b)	25	39.00	35·00	42·50	35·00	44·75	41·00	54·25	42·50	56·50	42·00	49·25	41·00
Mass Con. (b)	25	13·75	11·00	15·00	12·00	17·00	13·00	20·63	16·50	20·00	14·75	18·00	16·00
Mayflower (b)	25	2·63	1·88	4·00	1·88	3·50	2·75	3·00	2·50	2·50	1·00	2·00	1·50
Michigan (b)	25	7·00	5·50	9·00	5·50	7·50	6·12	9·50	7·00	9·00	6·50	9·00	7·00
Mohawk (b)	25	28·00	22·00	29·75	23·00	35·00	27·50	39·88	29·12	47·00	34·00	43·50	37·00
National (b)	25	·50	·50	1·63	1·50	.....	.....	1·00	1·00	1·00	1·00	1·00	1·00
Old Colony (b)	25	3·50	3·00	5·12	3·25	4·75	4·00	4·50	4·00	.....	.....	.....	.....
Old Dominion (c)	25	32·88	28·50	38·00	30·00	38·75	34·25	36·75	31·12	36·50	29·50	34·50	30·00
Osceola (b)	25	85·50	79·50	90·00	81·00	95·00	82·00	89·00	81·75	90·50	83·00	90·00	86·50
Parrot (a)	10	50·75	45·12	51·50	47·00	54·50	50·38	58·50	49·75	57·00	49·00	55·50	51·50
Phœnix Con. (b)	25	.....	.....	5·12	4·25	5·00	4·50	5·00	3·25	4·00	3·25	4·00	3·25
Quincy (b)	25	180·00	163·00	180·00	165·00	177·50	170·00	187·00	175·00	179·00	168·00	176·00	170·00
Rhode Island (b)	25	5·00	4·00	10·00	4·50	8·50	5·38	6·50	5·50	6·00	4·00	4·75	3·00
Santa Fé (j)	10	7·25	6·00	8·50	6·00	9·00	7·25	10·25	8·00	9·00	6·50	7·75	6·00
Tamarack (b)	25	344·00	320·00	339·00	330·00	350·00	325·00	350·00	330·00	342·00	315·00	345·00	330·00
Tecumseh (b)	25	2·00	1·63	3·00	1·75	3·00	1·50	2·00	1·50	2·50	1·50	2·50	2·00
Tennessee (k)	25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	23·00	21·25
Tri-Mountain (b)	25	23·25	19·75	29·00	20·75	43·00	27·00	50·00	34·00	49·00	37·00	55·00	46·50
Union (b)	25	3·50	2·36	3·75	3·00	5·00	3·50	4·00	2·50	.....	.....	.....	.....
Utah Con. (h)	5	34·50	31·75	36·25	32·50	37·50	31·50	37·25	33·00	34·50	28·00	33·00	29·50
Victoria (b)	25	4·00	3·63	5·25	3·38	5·00	4·25	5·00	3·63	5·00	3·75	5·00	4·50
Washington (b)	25	·75	·50	·80	·55	·65	·50	·55	·20	.....	.....	·25	·25
Winona (b)	25	6·75	4·50	10·00	5·50	8·00	4·00	5·00	4·25	4·50	3·00	3·25	2·00
Wolverine (b)	25	50·00	46·50	56·00	49·00	56·00	50·00	55·00	50·00	68·00	53·00	60·00	56·50
Wyandotte (b)	25	2·00	1·75	3·00	1·50	3·00	1·38	2·00	1·25	2·00	1·00	1·75	1·00
Gold:													
Centennial-Eureka (h)	25	25·25	23·00	28·00	24·00	35·00	27·50	34·75	31·00	34·00	28·50	31·50	30·00
Cochiti (j)	10	13·12	9·75	10·75	8·50	10·00	8·50	8·50	7·12	8·00	5·25	7·00	5·25
Cons. Mercur (h)	5	.....	.....	.....	.....	.....	.....	4·00	3·12	3·75	3·00	3·63	2·63
Daly-West (h)	20	30·75	30·00	34·00	30·25	36·25	34·00	36·00	35·00	37·00	35·00	41·50	40·00
Melones (e)	10	1·25	1·00	1·25	1·25	1·25	1·25	.....	.....	2·00	.....	.....	.....
Merced (e)	15	6·00	5·00	6·00	5·00	5·25	5·00	5·12	5·00	5·12	5·00	5·00	4·75
N. Amer. Dredging	5	1·00	·75	·75	·75	·50	·50	·50	·10	.....	.....	5·75	5·00
Santa Ysabel (e)	5	2·50	2·25	2·12	2·00	2·00	1·25	1·25	1·00	.....	.....	1·00	·50
United States (h)	25	11·00	9·50	13·50	9·75	19·88	12·25	24·00	18·36	24·00	18·00	21·50	19·00
Victor (d)	5	·25	·25	·80	·80	.....	.....	.....	.....	.....	.....	.....	.....
Zinc:													
Am. Z. L. & Sm. (g)	25	12·50	11·50	12·50	8·50	11·00	8·50	17·00	8·25	16·50	12·00	15·00	13·00
Continental (g)	10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Miscellaneous:													
Ætna (e)	5	·75	·75	1·00	·75	·75	·75	·75	·75	·75	·75	.....	.....
Bonanza (d)	25	1·25	1·00	1·50	1·00	1·88	1·12	1·75	1·25	1·63	1·00	1·38	1·12
Boston (e)	10	6·75	5·00	7·50	6·00	7·50	6·75	7·00	6·50	6·00	5·50	.....	.....
Central Oil	25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Catalpa (d)	10	.20	.20	.....	.....	.....	.....	·22	·21	·20	·20	·15	·15
Crescent (d)	10	·10	·10	·18	·18	.....	.....	.....	.....	.....	.....	.....	.....
Dominion Coal (f)	100	39·75	32·75	38·00	34·25	40·50	36·00	39·00	36·00	37·50	32·00	44·00	33·50
Dominion Coal, pref. (f)	100	110·00	108·00	110·00	109·50	111·00	110·00	115·00	111·50	115·50	114·50	117·00	114·00
Mont. Coal & Coke (a)	25	7·00	6·00	6·50	4·00	6·50	5·00	7·25	5·50	5·50	4·00	5·00	4·50
Napa (e)	7	.....	.....	4·00	.....	5·00	4·00	4·50	4·00	.....	.....	4·25	.....
New England Gas & Coke	100	14·75	10·00	14·00	11·50	13·36	12·00	13·12	10·00	12·00	10·00	11·60	6·50
New Idria (e)	5	10·00	9·00	.....	.....	9·00	9·00	.....	.....	.....	.....	.....	.....
Shawmut Oil	25	.....	.....	.....	.....	.....	.....	10·00	10·00	16·00	15·15	.....	.....
United States Oil	25	.....	.....	.....	.....	17·00	12·50	15·50	13·00	15·00	12·50	13·00	11·00
Total sales	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

FLUCTUATIONS IN MINING STOCKS AT BOSTON DURING 1901.—*Continued.*

Name of Company.	July.		August.		September.		October.		November.		December.		Sales. No. of Shares.
	H.	L.	H.	L.	H.	L.	H.	L.	H.	L.	H.	L.	
Copper:													
Adventure Con. (*b*)	$26·75	$21·00	$32·50	$23·50	$32·50	$21·00	$25·88	$26·50	$24·50	$21·00	$23·00	$15·75	209,308
Allouez (*b*)	3·50	2·88	6·00	3·00	6·25	2·63	5·00	1·88	5·00	4·50	4·50	2·75	71,888
Amalgamated (*a*)	124·25	110·00	122·50	110·00	129·00	88·50	91·25	83·50	89·00	72·50	76·00	60·00	1,597,129
Anaconda (*a*)	48·25	43·50	48·50	43·00	47·25	34·25	37·00	34·50	35·50	32·00	32·00	29·00	32,147
Arcadian (*b*)	17·00	15·00	15·75	12·00	14·00	8·50	9·50	5·12	9·00	5·00	5·88	3·00	98,157
Arnold (*b*)	3·00	2·00	3·00	1·50	3·00	1·75	2·00	1·25	1·50	1·25	1·09	·50	26,911
Ash Bed (*b*)					·25				·25				2,400
Atlantic (*b*)	38·00	35·00	38·00	35·00	43·00	32·75	40·50	30·25	41·50	36·00	40·50	24·36	65,564
Baltic (*b*)	55·00	49·00	57·00	50·00	58·00	42·00	47·00	39·88	48·00	41·00	45·00	31·00	160,486
Bingham (*h*)	24·88	21 00	43·75	20·50	42·25	32·00	33·00	28·00	30·00	27·00	28·50	23·00	218,894
Boston & Mont. (*a*)													48,370
British Columbia, Ltd. (*i*)	15·75	15·75	14·50	13·25	15·00	15·00	15·50	9·00	14·00	12·25			30,268
Butte & Boston (*a*)													226,766
Calumet & Hecla (*b*)	790·00	730·00	746·00	700·00	730·00	660·00	680·00	630·00	665·00	622·00	645·00	550·00	5,658
Centennial (*b*)	31·25	26·25	31·50	26·75	30·75	19·50	21·75	15·50	18·75	15·50	16·50	10·50	244,408
Copper Range (*b*)	79·75	71·50	83·00	74·00	83·00	53·00	63·00	54·00	69·00	58·00	66·00	44·00	278,772
Elm River (*b*)	5·75	4·25	5·36	4·00	6·00	3·00	4·00	3·00	4·00	3·25	3·00	1·75	63,421
Franklin (*b*)	18·00	16·50	19·50	17·00	22·50	16·00	18·00	16·50	17·00	16·00	16·00	11·30	96,751
Humboldt (*b*)					·50	·25	·13	·10					3,175
Isle Royale (*b*)	45·75	41·00	43·00	38·75	41·50	25·00	28·00	23·00	25·00	21·50	22·50	18·50	245,972
Mass Con. (*b*)	19·88	16·75	36·36	20·00	37·63	25·00	28·75	23·50	25·50	22·00	25·00	15·00	323,873
Mayflower (*b*)	2·00	1·00	3·00	1·50	3·88	2·00	5·63	3·00	4·25	3·25	3·50	1·50	93,174
Michigan (*b*)	15·00	8·75	19·00	12·50	19·75	12·50	16·00	12·00	14·88	13·00	13·00	7·00	139,692
Mohawk (*b*)	44·50	39·50	53·50	41·00	56·25	41·00	46·00	40·25	43·50	40·75	40·50	25·50	297,274
National (*b*)	1·75	1·25	4·50	1·50	4·00	1·75	5·25	1·75	2·25	2·00	1·75	1·50	20,280
Old Colony (*b*)	7·00	2·00	5·00	3·63	5·25	3·50	5·25	4·00	4·88	3·75	4·36	2·50	65,491
Old Dominion (*c*)	32·00	28·50	35·00	29·00	35·00	27·00	29·75	24·75	27·25	24·25	25·88	21·00	275,689
Osceola (*b*)	94·00	87·00	111·00	94·00	120·00	95·00	104·00	94·00	102·00	91·00	98·00	72·00	168,790
Parrot (*a*)	51·50	50·00	53·50	50·00	53·75	37·00	41·50	36·25	37·88	34·00	35.00	26·50	160,874
Phœnix Con. (*b*)	5·00	4·00	6·25	4·25	8·75	6·25	7·25	5·88	6·25	5·50	6·00	3·50	48,074
Quincy (*b*)	180·75	170·00	180·00	170·00	180·00	153 00	165·00	155·00	160·00	152·00	155·00	125·00	13,718
Rhode Island (*b*)	5·75	3·75	6·36	4·00	7·12	4·50	5·00	3·75	4·00	3·50	4·00	3·00	99,768
Santa Fé (*j*)	7·00	6·50	8·00	6·50	7·75	4·75	5·75	4·00	5·00	4·00	4·00	2·50	100,661
Tamarack (*b*)	350·00	342·00	350·00	343·00	360·00	280·00	305·00	280·00	290·00	265·00	275·00	230·00	11,924
Tecumseh (*b*)	2·25	2·00	2·88	1·75	3·00	1·00	2·25	1·00	2·00	1·50	1·75	·50	78,070
Tennessee (*k*)			22·00	21·00	18·50	17·00							1,952
Tri-Mountain (*b*)	55·50	50·50	60·00	50·00	57·00	42·25	45·00	39·00	48·50	40·00	43·00	28·00	231,320
Union (*b*)	3·00		3·25	3·00	3·36	3·00			2·00				22,411
Utah Con. (*h*)	32·50	20·00	39·00	28·00	39·00	23·00	26·00	22·00	25·00	22·00	23·00	18·63	228,600
Victoria (*b*)	8·00	4·88	10·00	6·50	12·00	7·25	9·00	6·50	7·50	6·50	6·50	4·00	207,651
Washington (*b*)	·25	·25	·25	·25			·13						5,530
Winona (*b*)	3·12	2·00	4·50	2·50	4·50	2·36	3·00	2·00	2·50	2·00	2·25	2·50	109,433
Wolverine (*b*)	62·00	57·50	67·00	61·00	74·00	56·00	66·50	57·50	60·00	56·75	58·50	44·00	99,765
Wyandotte (*b*)	2·50	1·75	3·12	1·25	2·75	1·50	1·88	1·00	1·75	1·00	1·25	1·00	35,378
Gold:													
Centennial-Eureka (*h*)	31·50	30·00											75,102
Cochiti (*j*)	5·50	4·50	5·63	5·00	5·50	3·75	4·50	3·00	4·00	3·75	4·00	1·75	103,287
Cons. Mercur (*h*)	3·00	1·88	3·00	2·88	3·00	2·50	2·50	2·00	2·00	1·25	1·63	1·25	77,359
Daly-West (*h*)	43·50	43·50	43·00	40·00	43·50	33·00	37·00	32·50	33·00	28·00	30·50	30·00	12,020
Melones (*e*)													4,720
Merced (*e*)	5·00	5·00	4·00	4·00	5·00	3·50							10,540
N. Amer. Dredging					1·63								28,895
Santa Ysabel (*e*)			·50	·50	1·00	·75	·50	·50					9,586
United States (*h*)	20·75	17·00	20·25	17·75	22·00	16·25	17·63	15·50	16·50	14·75	15·25	13·00	462,458
Victor (*d*)													
Zinc:													
Am. Z. L. & Sm. (*g*)	14·50	13·00	13·00	12·00	12·00	8·75	10·00	9·36	10·00	9·00	10·50	9·00	47,027
Continental (*a*)	3·00										2·50	1·50	1,700
Miscellaneous:													
Ætna (*e*)											·50		2,700
Bonanza (*d*)	3·00	1·25	1·63	1·25	2·30	1·00	1·25	1·00	1·12	1·00	1·00	·75	58,361
Boston (*e*)													7,790
Central Oil					8·50	8·00	8·00	8·00	9·00	7·50			6,391
Catalpa (*d*)									·18	·18			5,150
Crescent (*d*)											·10		825
Dominion Coal (*f*)	40·25	37·00	40·25	37·00	45·25	39·88	48·25	43·25	49·00	46·00	48·50	46·00	156,824
Dominion Coal, pref. (*f*)	116·00	114·00	118·00	116·00	117·00	115·00	119·00	116·36	118·00	118·00	120·00	116·00	4,460
Mont. Coal & Coke (*a*)	5·25	4·50	5·50	5·00	5·00	4·00	4·50	4·25	4·25	3·50	4·50	3·88	19,420
Napa (*e*)	4·00						4·00						1,250
N. England Gas & Coke	9·00	5·50	8·00	5·25	8·00	6·00	7·00	4·00	9·75	8·00	6·36	4·75	83,120
New Idria (*e*)			6·00	6·00									260
Shawmut Oil													808
United States Oil	13·00	10·50	16·00	11·25	15·75	12·00	14·25	12·00	14·75	12·50	13·36	10·25	49,945
Total sales													7,862,145

(*a*) Montana; (*b*) Michigan; (*c*) Arizona; (*d*) Colorado; (*e*) California; (*f*) Nova Scotia; (*g*) Missouri; (*h*) Utah, (*i*) British Columbia; (*j*) New Mexico; (*k*) Tennessee.

FLUCTUATIONS OF MINING STOCKS AT COLORADO SPRINGS, COLO., DURING 1901.

Name of Company.	Par Value	January.		February.		March.		April.		May.		June.	
		H.	L.	H.	L.	H.	L.	H.	L.	H.	L.	H.	L.
Acacia	$1·00	·30	·22	·23	·18	·18	·16	·17	·12	·13	·11	·15	·14
Alamo	1·00	·13	·11	·16	·15	·14	·13	·14	·13	·14	·13	·15	·14
American Con	1·00	·07	·06	·07	·06	·06	·05	·06	·05	·05	·04	·05	·04
Anaconda	5·00	·50	·42	·49	·43	·46	·40	·45	·41	·40	·39	·40	·37
Anchor	1·00	·03	·02	·03	·02	·03	·02	·03	·02	·02	·02	·03	·03
Antelope	1·00	·03	·02	·03	·05	·02	·02	·02	·02	·02	·02	·02	·02
Aola	1·00	·06	·05	·06	·05	·05	·04	·04	·02	·04	·04	·04	·04
Argentum-Juniata	2·00	·31	·22	·34½	·25	·26	·25	·27	·25	·19	·16	·20	·17
Banner	1·00	·03	·03	·04	·03	·04	·03	·03	·03	·03	·03	·03	·02
Battle Mt. Con	1·00	·26	·20	·26	·25	·28	·24	·28	·20	·21	·21	·19	·11
Black Bell	1·00	·13	·10	·14	·11	·13	·12	·14	·12	·12	·10	·14	·11
Blue Bell	1·00	·15	·14	·22	·17	·19	·16	·18	·14	·17	·16	·17	·16
Buckhorn	1·00	·07	·05	·06	·05	·05	·04	·04	·03	·04	·04	·04	·04
Cadillac	1·00	·03	·02	·03	·03	·02	·02	·02	·02	·02	·01	·03	·03
Central Con	1·00	·07	·06	·06	·05	·08	·06	·10	·09	·09	·08	·09	·07
Champion	1·00	·07	·06	·07	·06	·06	·05	·06	·04	·06	·05	·05	·04
Chicolo	1·00	·03	·02	·03	·03	·03	·03	·03	·03	·03	·02	·03	·02
C. K. & N	1·00	·03	·03	·03	·03	·03	·02	·03	·02	·02	·02	·03	·01
C. C. Columbia	1·00	·13	·11	·15	·12	·16	·14	·14	·11	·17	·14	·22	·15
C. C. G. Ext	1·00	·16	·12	·14	·14	·14	·10	·13	·08	·13	·07	·09	·09
C. C. & Man	1·00	·10	·09	·10	·09	·09	·08	·11	·10	·09	·07	·08	·08
Creede & C. C	1·00	·13	·08	·15	·08	·10	·08	·11	·09	·08	·06	·10	·08
Cripple Creek Con	1·00	·13	·10	·12	·10	·12	·11	·11	·10	·08	·07	·09	·08
Dante	1·00	·10	·09	·17	·08	·08	·07	·08	·07	·06	·06	·07	·07
Eclipse	1·00	·09	·08	·10	·10	.....	.....	·10	·09	·13	·06	·17	·15
Elkton Con	1·00	1·90	1·50	1·91	1·85	1·62	1·60	1·79	1·60	1·79	1·71	1·88	1·75
El Paso G	1·00	·53	·45	·60	·55	·50	·44	·47	·41	·39	·36	·51	·44
F. Rawlings	1·00	·25	·10	·15	·13	·25	·15	·27	·20	·30	·23	·28	·27
Findley	1·00	·14	·11	·14	·12	·14	·11	·13	·11	·13	·12	·12	·11
Gold Sovereign	1·00	·09	·07	.....	.....	·07	·06	·06	·06	·56	·08	·06	·06
Golden Fleece	1·00	·30	·23	·40	·30	·40	·28	·41	·35	·40	·40	·40	·39
Hayden G	1·00	·02	·02	·02	·02	·02	·01	·02	·01	·02	·02	·02	·02
Ingham Con	1·00	·21	·19	·21	·18	·29	·18	·19	·16	·20	·18	·19	·18
Ironclad	·50	·06	·05	·06	·05	·07	·06	·06	·05	·07	·06	·07	·06
Isabella	1·00	·72	·62	·86	·69	·77	·67	·75	·65	·66	·64	·63	·55
Jack Pot	1·00	·73	·50	·63	·57	·57	·50	·54	·50	·52	·50	·51	·47
Josephine	1·00	·03	·02	·62	·02	·02	·01	·01	·01	·02	·02	·02	·02
Key West	1·00	·03	·03	·03	·03	·03	·02	·03	·02	·02	·02	·02	·02
Lexington	1·00	·13	·10	·15	·10	·10	·08	·08	·07	·09	·03	·09	·06
Magnet Rock	1·00	·04	·03	·04	·03	·03	·03	·03	·03	·02	·02	·03	·02
Margaret	1·00	·04	·02	·03	·03	·03	·02	·02	·01	·02	·02	·02	·01
Margery	1·00	·03	·02	·04	·03	·03	·03	·03	·03	·03	·02	·02	·02
Midway	1·00	·05	·04	·04	·04	·04	·03	·04	·03	·03	·03	·04	·03
M. J. T	1·00	·05	·03	·04	·04	·04	·03	·03	·03	·02	·02	·03	·02
Mobile	1·00	·04	·03	·04	·03	·04	·03	·03	·02	·03	·02	·04	·03
Mollie Dwyer	1·00	·04	·03	·07	·06	·06	·05	·06	·05	·04	·04	·06	·05
Mollie Gibson	1·00	·30	·20	·24	·21	·28	·21	·31	·22	·30	·24	·50	·42
Monarch	1·00	·10	·09	·09	·08	·08	·05	·05	·05	·05	·05	·05	·04
Montreal	1·00	·05	·04	·04	·04	·05	·03	·04	·03	·04	·03	·04	·03
Moon-A'c'r	1·00	·30	·20	·30	·22	·34	·28	·32	·28	·30	·26	·27	·25
Morning Star	1·00	·05	·03	·04	·04	·04	·03	·04	·02	·03	·03	·03	·03
National	1·00	·11	·09	·11	·10	·09	·05	·06	·05	·04	·04	·05	·04
Nellie V	1·00	·08	·06	·08	·07	·06	·05	·06	·05	·05	·05	·06	·05
New Haven	1·00	·09	·07	·12	·09	·10	·07	·09	·08	·07	·06	·07	·07
Olive Branch	1·00	·05	·04	·05	·04	·04	·03	·04	·02	·04	·03	·03	·03
Oriole	1·00	·05	·03	·04	·04	·04	·03	·03	·03	·03	·03	·03	·03
Orphan	1·00	·20	·13	·18	·15	·17	·11	·17	·23	·16	·14	·16	·14
Pelican	1·00	·03	·02	·03	·02	·03	·02	·02	·02	·02	·02	·02	·02
Pharmacist	1·00	·09	·07	·11	·11	·14	·10	·13	·10	·09	·03	·09	·08
Pilgrim	1·00	·12	·08	·11	·11	·14	·07	·09	·08	·09	·07	·08	·07
Pinnacle	1·00	·20	·15	·22	·17	·19	·12	·12	·10	·11	·10	·11	·10
Portland	1·00	3·50	3·20	3·25	3·03	3·05	2·85	3·07	3·01	3·05	3·01	3·10	3·00
Prince Albert	1·00	·06	·05	·06	·06	·05	·05	·05	·05	·05	·05	·05	·04
Princess	1·00	·06	·05	·06	·05	·05	·03	·06	·05	·05	·04	·05	·04
Progress	1·00	·06	·05	·08	·07	·07	·05	·06	·06	·05	·05	·06	·05
Republic	1·00	·08	·07	·09	·08	·08	·06	·07	·06	·06	·04	·07	·05
Robert Burns	1·00	·08	·04	·05	·05	·05	·04	·05	·04	·05	·03	·04	·03
Rose Maud	1·00	·09	·07	·08	·07	·07	·06	·07	·06	·06	·03	·06	·05
Rose Nicol	1·00	·12	·10	·08	·07	·10	·07	·08	·07	·07	·05	·09	·07
Uncle Sam	1·00	·05	·04	·05	·04	·04	·04	·04	·03	·04	·04	·04	·03
Vindicator	1·00	1·40	1·20	1·35	1·28	1·35	1·00	1·30	1·00	1·30	1·10	1·25	1·15
Va. M	1·00	·10	·07	·10	·08	·08	·07	·08	·05	·07	·07	.....	.....
Work	1·00	·22	·19	·23	·20	·22	·19	·19	·18	·17	·15	·19	·15
Total sales	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

FLUCTUATIONS OF MINING STOCKS AT COLORADO SPRINGS, COLO., DURING 1901.—*Continued.*

Name of Company.	July.		August.		September.		October.		November.		Decemb'r.		Sales, No. of Shares.
	H.	L.	H.	L.	H.	L.	H.	L.	H.	L.	H.	L.	
Acacia	·15	·13	·17	·15	·17	·14	·17	·15	·17	·13	·13	·11	498,888
Alamo	·15	·13	·14	·13	·14	·13	·15	·13	·14	·13	·14	·13	782,800
American Con	·06	·05	·05	.....	·05	.....	·05	·03	.....	.....	·04	·03	100,000
Anaconda	·38	·30	·36	·31	·36	·30	·30	·24	·30	·25	·26	·25	198,797
Anchor	·03	....	·03	.....	·02	.....	·02	.....	·02	.....	·02	.....	14,000
Antelope	·02	....	·02	.....	·02	.....	·02	.....	·02	.....	·02	.....	61,500
Aola	·04	·03	·03	.....	·04	.....	·04	·03	·04	·03	·03	.....	292,900
Argentum-Juniata	·17	·14	·17	·10	·15	·09	·10	·06	·09	·05	·06	·05	173,027
Banner	·02	....	·02	.....	·03	.....	·02	.....	.....	.....	·04	.....	77,500
Battle Mt. Con	·18	·17	·18	·15	·20	·16	·20	·17	·18	·15	·18	·15	175,509
Black Bell	·11	·08	·11	·10	·11	·10	·10	·07	·09	·08	·10	·08	82,500
Blue Bell	·16	·15	·17	·14	·17	·15	·16	·13	.....	.....	·14	·08	130,700
Buckhorn	·04	·03	·04	·03	·04	·03	·04	·03	·04	·03	·03	.....	65,500
Cadillac	·02	....	·03	·02	·02	.....	·02	·01	·02	.....	·02	.....	74,000
Central Con	·08	·05	·09	·07	·11	·08	·10	·03	·09	·07	·07	·06	520,000
Champion	·06	·05	·05	·04	·06	·04	.....	.....	·04	.....	·04	·03	68,028
Chicolo	·02	....	·02	.....	·02	.....	·02	.....	·02	.....	·02	.....	84,000
C. K. & N	·03	....	·03	·02	·02	.....	·03	·02	·02	.....	·03	.....	656,200
C. C. Columbia	·23	·21	·26	·23	.....	.....	.....	.....	.....	.....	.....	.....	427,500
C. C. G. Ext	·09	·08	·09	·08	·09	·06	·08	·05	·08	·05	·08	·06	61,097
C. C. & Man	·08	·07	·08	·07	·10	·07	·08	·07	·07	·05	·06	·05	274,779
Creede & C. C	·09	·07	·10	·07	·12	·07	·10	·05	·08	·05	·05	·04	11,000
Cripple Creek Con	·08	·07	·10	·08	·09	·08	·09	·07	·10	·08	·09	·08	360,000
Dante	·06	·05	·08	·05	·12	·04	·05	·03	·05	·04	·05	·04	222,300
Eclipse	·13	·11	·14	·11	·13	·11	·13	·12	.....	.....	.....	.....	1,911,700
Elkton Con	1·72	1·64	1·88	1·76	1·78	1·70	1·74	1·65	1·52	1·48	1·49	1·39	165,451
El Paso G	·46	·43	·57	·47	·61	·52	·80	·60	·76	·73	·65	·63	1,586,122
F. Rawlings	·20	·15	·21	·15	·23	·15	·20	·15	·20	·15	·15	·10	93,900
Findley	·10	·09	·10	·09	·10	·08	·09	·07	·09	·07	·09	·08	189,266
Gold Sovereign	.....	.....	·06	·04	·05	·04	·04	·03	.....	.....	.....	.....	150,000
Golden Fleece	·39	·35	·40	·34	·40	·30	.....	.....	.....	.....	·40	·20	58,800
Hayden G	·02	....	·02	·01	·02	.....	·02	.....	.....	.....	.....	.....	39,000
Ingham Con	·17	·13	·18	·14	·16	·12	·17	·12	·13	·12	·13	·12	166,895
Ironclad	·07	·06	·06	·04	·06	·05	·06	·04	·05	·02	·03	·02	857,129
Isabella	·45	·40	·63	·43	·60	·40	·50	·40	·40	·35	·34	·41	1,234,828
Jack Pot	·45	·40	·47	·39	·45	·37	·45	·34	·42	·39	·40	·35	125,050
Josephine	·02	....	·02	.....	·02	.....	·02	·02	.....	.....	.....	.....	50,500
Key West	·02	....	·02	.....	·02	.....	·02	.....	·02	.....	.....	.....	128,000
Lexington	·08	·07	·07	·06	·07	·05	·07	·06	·07	·06	·07	·05	234,700
Magnet Rock	·03	·02	·03	.....	·03	·02	·03	·02	·02	.....	.....	.....	134,332
Margaret	·02	·01	·02	.....	·02	....	·02	·01	·02	.....	·02	.....	40,000
Margery	·03	·02	·02	.....	·02	.....	·04	.....	·02	.....	·02	.....	64,500
Midway	·04	·03	·07	·03	·04	·03	·07	·02	·04	.....	·04	.....	638,500
M. J. T	·03	·02	·02	.....	·02	.....	·02	.....	·02	.....	·02	.....	126,000
Mobile	·03	·02	·03	·02	·03	·02	·03	·02	·02	.....	·02	.....	157,000
Mollie Dwyer	·07	·06	·07	·06	·08	·07	·07	·03	·05	·04	·03	.....	1,226,518
Mollie Gibson	·37	·32	·40	·30	·38	·20	·32	·15	·18	·13	·15	.....	193,418
Monarch	·05	·04	·05	·04	·05	·04	·04	·03	·04	·03	·03	.....	79,800
Montreal	·03	·02	·04	·03	·04	·03	·04	·01	·03	.....	·03	.....	45,483
Moon-A'c'r	·33	·29	·32	·24	·34	·26	·31	·26	·28	·24	·25	·20	85,000
Morning Star	·03	·02	·04	·02	·05	·04	·05	·03	·04	.....	·04	·03	1,033,669
National	·04	·03	·04	·03	·05	·03	·04	·03	·03	·02	·02	.....	495,500
Nellie V	·07	·05	·06	·05	·05	.....	·05	·03	·05	·04	·04	.....	350,350
New Haven	·07	·06	·05	·02	·06	·05	·07	·04	·06	·04	·05	·04	384,450
Olive Branch	·03	·02	·05	·02	·04	·03	·04	·03	·03	·02	·03	·02	226,000
Oriole	·03	....	·04	·03	·04	·03	·03	·02	·02	.....	·02	.....	68,607
Orphan	·18	....	·18	·17	·20	·17	·22	·19	·10	·07	.....	.....	87,500
Pelican	·02	....	·02	.....	·02	.....	·02	.....	.....	.....	.....	.....	211,000
Pharmacist	·09	·07	·10	·08	·09	·08	·08	·06	·06	·03	·06	·05	628,500
Pilgrim	·09	·07	·08	·06	·07	·05	·06	·04	·04	·03	·05	·03	69,800
Pinnacle	·08	·05	·09	·07	·10	·07	·11	·07	·09	·06	·09	·06	118,350
Portland	3·02	3·00	3·15	3·00	3·10	2·90	3·06	2·98	3·00	2·84	3·00	2·75	74,800
Prince Albert	·05	·04	·05	·04	·05	·04	·05	·04	·04	·02	·04	·03	363,200
Princess	·05	·04	·05	·03	·05	·03	·04	·02	·04	·02	·03	·02	81,000
Progress	·06	·05	·06	·05	·05	·05	·05	·04	·04	·03	·04	.....	228,500
Republic	·05	·04	·06	·04	·05	·04	·03	·02	·04	·03	·04	.....	176,200
Robert Burns	·04	·03	·04	·03	·05	·02	·06	·05	·03	·02	·02	.....	162,500
Rose Maud	·05	·04	·06	·05	·07	·05	·07	·05	·06	·06	·06	·05	309,028
Rose Nicol	·08	·06	·07	·06	·07	·06	.....	.....	·07	·05	·06	·03	117,500
Uncle Sam	·03	·02	·04	·02	·04	·03	·03	·02	·03	·02	·02	....	73,000
Vindicator	1·36	1·16	1·20	1·10	1·19	1·12	1·40	1·06	1·24	1·19	1·22	1·17	86,660
Va. M	·06	·04	·06	·04	·06	·03	·04	·03	·05	·03	·06	.....	50,300
Work	·14	·13	·16	·13	·15	·13	·13	·12	·11	·10	·10	·09	305,650
Total sales	....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	20,412,081

FLUCTUATIONS OF MINING STOCKS AT NEW YORK DURING 1901.

Name and Location of Company	Par Value.	January.		February.		March.		April.		May.		June.	
		H.	L.	H.	L.	H.	L.	H.	L.	H.	L.	H.	L.
Adams Co., g., Colo.	$10	·25	.....	·25	·15	.....	.....	.....	.....	.....	.....	.....	.....
Alamo, g., Colo.	1	·13	·12	·17	·15	·15	·13	.....	.....	·15	·14	·15	.....
Alice, g., Mont.	25	·84	·45	·48	.....	·45	·40	·40	·37	·50	·42	·47	·45
Amalgamated, c., Mont.	100	93·38	83·75	94·00	88·38	104·50	94·50	128·75	99·88	123·63	101·50	130·00	117·00
Anaconda, c., Mont.	25	48·75	40·75	47·00	42·25	49·38	45·00	54·25	45·75	51·63	42·00	51·38	47·75
Anaconda, g., Colo.	5	·45	·40	·46	·45	·46	·40	·43	.....	·42	·20	·40	.....
Argentum-Jun., g.s.l., Colo.	2	·29	·27	·26	·25	.28	·24	·25	·21	·21	·19	·21	·19
Best & Belcher, g.s., Nev.	3	.....	.....	·26	.....	.....	.....	·20	.....	·30	·25	·32	·19
Breece, l.s., Colo.	25	.....	.....	.....	.....	1·50	.....	1·50	.....	1·68	1·60	1·70	1·55
British Columbia, c., B. C.	10	22·75	17·63	21·63	18·50	21·13	19·75	20·25	16·25	19·00	16·00	18·50	15·00
Brunswick, g., Cal.	1	·28	·22	·40	·28	·29	·23	·25	·20	·20	·15	·22	·15
Cable Con., g., Colo.	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Catalpa, s.l., Colo.	10	·14	.....	·15	.....	.....	.....	.....	.....	·14	.....	·14	·13
Chollar, s.g., Nev.	3	.....	.....	.....	.....	.....	.....	.....	.....	·12	.....	.....	.....
Chrysolite, s.l., Colo.	50	·10	.....	·07	·06	·08	·06	.....	.....	·06	.....	·06	.....
Comstock Tunnel, s.g., Nev.	100	·05	.....	·05	·04	·08	·05	·08	·05	·06	·05	·07	·06
Comstock Tunnel Bonds.	100	·06	·05	·04	.....	.....	.....	.....	.....	.....	.....	.....	.....
Con. Cal. & Va., s.g., Nev.	2½	2·80	1·55	1·85	1·50	2·30	1·50	2·50	2·15	2·55	1·80	2·55	2·15
Creede & Crip. Creek, g., Colo.	1	·12	·09	.....	.....	·10	.....	.....	.....	·10	·09	·09	·08
Crescent, s.l., Colo.	10	·12	.....	.....	.....	·13	·12	·12	.....	·12	.....	.....	.....
Cripple Creek Con., g., Colo.	1	·13	·10	·13	·11	·12	.....	·12	·08	.....	.....	·10	·09
Crown Point, g.s., Nev.	3	·17	.....	.....	.....	·15	·10	.....	.....	·17	.....	·10	.....
Daly, g., Utah	20	.....	.....	.....	.....	1·50	.....	.....	.....	1·50	.....	1·30	.....
Deadwood-Terra, g., S. Dak.	100	.....	.....	.....	.....	·53	·52	.....	.....	.....	.....	.....	.....
Dunkin, s., Colo.	1	·15	·13	.....	.....	·11	·10	.....	.....	·12	.....	.....	.....
Elkton Con., g., Colo.	1	1·85	.....	.....	.....	.....	.....	1·60	.....	.....	.....	1·79	1·70
Fanny Rawlings, g., Colo.	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Gold Dollar, g., Colo.	1	·26	·25	·28	·26	·28	.....	·26	.....	·21	.....	.....	.....
Golden Fleece, g.s., Colo.	1	·25	.....	·30	·26	·34	·20	·42	·33	·40	·38	.....	.....
Gould & Curry, g.s., Nev.	3	.....	.....	.....	.....	.....	.....	.....	.....	·12	.....	.....	.....
Hale & Norcross, s.g., Nev.	3	.....	.....	·20	·19	·15	.....	·22	.....	·27	·22	·26	.....
Hart, g.,Colo.	1	·14	.....	.....	.....	·14	.....	.....	.....	·13	.....	·14	.....
Homestake, g., S. Dak.	100	78·00	75·00	80·00	.....	.....	.....	100·00	.....	.....	.....	.....	.....
Horn Silver, s.l., Utah.	25	1·20	1·15	1·45	1·15	1·20	1·10	1·20	1·10	1·30	1·10	1·50	.....
Iron Silver, s.l., Colo.	20	1·15	.....	·68	.....	·66	·64	·64	·63	.....	.....	.....	.....
Isabella, g., Colo.	1	·75	·65	·82	·70	·76	·67	·75	·69	·71	·68	·65	·56
Jack Pot, g., Colo.	1	·62	.....	·64	·60	.....	.....	·55	·54	.....	.....	.....	.....
Justice, s., Nev.	1	·12	·10	.....	.....	·08	.....	·10	.....	.....	.....	.....	.....
Kingston & Pembroke, l., Ont.	10	.....	.....	.....	.....	·25	.....	.....	.....	.....	.....	.....	.....
Lacrosse, g., Colo.	10	.....	.....	.....	.....	.....	.....	·10	.....	.....	.....	.....	.....
Leadville Con., g.s., Colo.	10	·08	·06	·08	·07	·06	·05	·07	.....	·07	·06	·06	·08
Little Chief, s.l., Colo.	1	·17	·15	·15	.....	·15	·14	·15	·14	·13	.....	·14	.....
Mexican, g.s., Nev.	3	·60	·30	.....	.....	.....	.....	·40	·34	·20	.....	·25	·18
Mollie Gibson, s., Colo.	5	·24	·22	·22	·20	·26	·23	·25	·23	·34	·28	·46	·34
Moon-Anchor, g., Colo.	5	.....	.....	.....	.....	·34	·32	.....	.....	.....	.....	.....	.....
Moulton, g., Mont.	25	·30	.....	.....	.....	.....	.....	.....	.....	.....	.....	·35	·30
Mt. Rosa, g., Colo.	1	.....	.....	.....	.....	.....	.....	·35	.....	.....	.....	.....	.....
Ontario, s.l., Utah.	100	7·00	6·50	7·63	6·25	11·00	7·88	10·00	9·00	8·50	8·00	9·50	8·00
Ophir, g.s., Nev.	3	·88	·65	·95	·60	·83	·64	1·05	·85	1·05	·85	1·20	·90
Pharmacist, g., Colo.	1	·10	·09	·13	·10	14	·12	·13	·09	·10	·09	·10	.....
Phœnix Con., g., Ariz.	1	·10	.....	·11	·09	·10	·09	·10	.....	·18	·08	·18	·12
Plymouth, g., Cal.	10	.....	.....	·10	.....	·10	.....	.....	.....	·10	·09	.....	.....
Portland, g., Colo.	10	.....	.....	3·20	.....	3·00	2·80	3·00	2·80	3·00	2·80	3·05	2·90
Potosi, g.s., Nev.	3	·26	.....	·18	.....	·20	.....	·12	·10	.....	.....	.....	.....
Quicksilver, q., Cal.	100	.....	.....	.....	.....	1·00	.....	3·00	1·55	5·00	2·00	5·25	4·00
Quicksilver, pref., Cal.	100	9·50	.....	.....	.....	8·00	7·00	10·88	9·25	12·75	10·00	12·50	10·00
Savage, s., Nev.	2½	·30	·17	.....	.....	.....	.....	·15	·12	.....	.....	.....	.....
Sierra Nevada, s., Nev.	3	·40	·20	·35	·20	.....	.....	·35	·30	·28	·15	·22	·18
Small Hopes, s.l., Colo.	20	·80	.65	·75	·70	·75	·70	·65	.....	.....	.....	.....	.....
Standard Con., g.s., Cal.	10	4·30	3·90	4·35	.....	4·20	4·10	4·25	4·15	3·80	3·57	3·85	3·75
Syndicate, g., Cal.	1	·12	.....	·12	.....	·10	.....	·09	.....	·09	·08	·08	.....
Tennessee, c., Tenn.	25	19·00	16·00	18·63	16·50	20·00	17·50	28·38	14·00	24·00	18·50	23·50	20·00
Union Con., s., Nev.	2½	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Union, c., N. C.	10	5·75	3·50	5·00	3·50	4·75	3·75	8·25	4·50	7·63	5·88	7·38	6·25
Work, g., Colo.	1	·20	·18	·23	.....	·20	·19	·19	.....	·20	·19	·17	·16
Yellow Jacket, s., Nev.	3	·18	14	.....	.....	·20	.....	·15	.....	.....	.....	·10	·08
Total sales.	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

THE NEW YORK MINING STOCK MARKET IN 1901.

The market was characterized by wide fluctuations with downward tendencies. Copper was the chief feature, and the dealings in Amalgamated formed a large part of the total transactions. The course of this stock has had few parallels on the exchange in recent years. From the low price of $83·75 in January, it rose

FLUCTUATIONS OF MINING STOCKS AT NEW YORK DURING 1901.—*Continued.*

Name and Location of Company.	July.		August.		Sept.		October.		November		December		Sales. No. of Shares.
	H.	L.	H.	L.	H.	L.	H.	L.	H.	L.	H.	L.	
Adams Con., g., Colo.	·20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	500
Alamo, g., Colo.	·15	·14	·15	·14	·15	·14	·15	·14	·14	.....	·14	·11	66,300
Alice, g., Mont.	.....	.....	.....	.....	.....	.....	·55	·44	·45	.....	.....	.....	8,610
Amalgamated, c., Mont.	124·25	109·00	122·75	110·00	120·00	88·63	93·00	83·38	88·38	72·50	76·30	60·50	10,657,494
Anaconda, c., Mont.	48·88	42·00	48·50	42·50	47·25	35·75	37·00	34·00	35·50	30·30	32·50	28·50	1,069,788
Anaconda, g., Colo.	·40	·32	·35	·34	·35	·32	·29	·28	·28	·23	.....	.....	14,500
Argentum-Jun., g.s.l., Colo.	·15	·17	·15	·12	·13	.....	·11	.....	·10	·08	.....	.....	34,800
Best & Belcher, g.s., Nev.	·22	·20	·23	·17	·22	.....	·18	·15	·19	·16	·15	·13	10,500
Breece, l. s., Colo.	.....	.....	.....	.....	.....	.....	1·50	1·20	1·25	1·20	.....	.....	3,675
British Columbia, c., B. C.	17·00	14·50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	25,700
Brunswick, g., Cal.	·20	·13	·11	·09	.....	.....	·12	·06	·14	.....	·18	·14	106,140
Cable Con., g., Colo.	.....	.....	.....	.....	·04	.....	·05	·04	.....	.....	.....	.....	5,000
Catalpa, s.l., Colo.	.....	.....	·14	.....	.....	.....	·14	.....	.....	.....	·14	.....	3,200
Chollar, s.g., Nev.	.....	.....	.....	.....	·08	·05	.....	.....	.....	.....	·08	·05	6,900
Chrysolite, s.l., Colo.	·08	·03	·06	.....	.....	.....	.....	.....	.....	.....	.....	.....	6,980
Comstock Tunnel, s.g., Nev.	·08	·04	·07	.....	·08	·07	·07	·06	·07	·06	·07	·03	143,300
Comstock Tunnel Bonds	.....	.....	·07	·06	.....	.....	·08	·06	·06	.....	·06	.....	75,000
Con. Cal. & Va., s.g., Nev.	2·35	1·95	2·50	1·80	1·90	1·65	1·90	1·75	1·85	1·60	1·75	1·65	29,220
Creede & Crip. Creek, g., Colo.	.....	.....	.....	.....	·08	.....	.....	.....	.....	.....	·10	·06	16,100
Crescent, s.l., Colo.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2,600
Cripple Creek Con., g., Colo.	·10	·09	·10	·09	·09	.....	·09	·07	·10	·07	·10	·06	73,100
Crown Point, g.s., Nev.	.....	.....	·09	.....	.....	.....	.....	.....	.....	.....	·08	·04	2,600
Daly, g., Utah	1·80	.....	.....	.....	.....	.....	.....	.....	.....	.....	1·80	.....	650
Deadwood-Terra, g., S. Dak.	.....	.....	.....	.....	·60	·55	·55	·50	.....	.....	.....	.....	2,755
Dunkin, s., Colo.	.....	.....	·12	·10	·08	.....	.....	.....	.....	.....	.....	.....	2,910
Elkton Con., g., Colo.	1·70	.....	.....	.....	1·70	.....	1·60	1·30	1·55	1·45	1·45	1·35	6,700
Fanny Rawlings, g., Colo.	.....	.....	.....	.....	·21	.....	·19	.....	·20	.....	.....	.....	1,700
Gold Dollar, g., Colo.	.....	.....	·20	·19	.....	.....	·10	.....	·18	·10	·10	.....	19,800
Golden Fleece, g.s., Colo.	·35	·30	·36	.....	.....	.....	·36	·20	·33	.....	.....	.....	11,800
Gould & Curry, g.s., Nev.	.....	.....	.....	.....	.....	.....	.....	.....	·07	·06	·06	.....	2,700
Hale & Norcross, s.g., Nev.	·25	.....	·30	·21	·15	.....	·20	·14	·20	·16	·20	·15	9,300
Hart, g., Colo.	.....	.....	.....	.....	·13	·12	.....	.....	.....	.....	.....	.....	3,800
Homestake, g., S. Dak.	.....	.....	.....	.....	104·00	.....	.....	.....	.....	.....	.....	.....	208
Horn Silver, s.l., Utah.	1·75	.....	1·75	.....	2·00	1·80	2·25	1·90	.....	.....	.....	.....	11,315
Iron Silver, s.l., Colo.	.....	.....	·65	·60	·65	.....	·65	.....	·64	·62	·65	.....	8,700
Isabella, g., Colo	·56	·42	·54	·43	·61	·50	·60	·42	·48	·33	·36	·30	48,850
Jack Pot, g., Colo.	·40	.....	.....	.....	·42	.....	.....	.....	.....	.....	.....	.....	1,800
Justice, s., Nev.	.....	.....	.....	.....	.....	.....	.....	.....	·04	·02	.....	.....	1,200
Kingston & Pembroke, l., Ont.	·25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1,300
Lacrosse, g., Colo.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	300
Leadville Con., g.s., Colo.	·07	·06	·08	·07	·09	·08	·08	·06	.....	.....	.....	.....	22,900
Little Chief, s.l., Colo.	·14	·13	·14	·13	·14	·12	·13	·12	·12	.....	·13	.....	23,600
Mexican, g.s., Nev.	·20	.....	·10	.....	·20	·18	·16	.....	·19	·18	·17	·14	9,000
Mollie Gibson, s., Colo.	·39	·36	·40	·33	·36	·30	·30	·18	·25	·20	.....	.....	38,150
Moon-Anchor, g., Colo.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	100
Moulton, g.. Mont.	·40	·35	·35	·30	·28	.....	·30	.....	.....	.....	.....	.....	2,400
Mt. Rosa, g , Colo.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	400
Ontario, s.l., Utah.	10·25	9·25	10·00	8·00	13·00	10·00	12·25	10·88	11·00	10·00	9·25	8·25	26,015
Ophir, g.s., Nev.	·92	·65	·90	·75	·95	·75	·85	·80	·84	·75	·80	·65	25,650
Pharmacist, g., Colo	·09	.....	.....	.....	·12	·08	·09	.....	·08	·06	.....	.....	72,100
Phœnix Con., g., Ariz.	·12	·09	·17	·09	·09	·08	·08	·07	·09	·07	·07	.....	19,880
Plymouth, g., Cal.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1,100
Portland, g., Colo.	3·00	2·90	2·95	2·90	3·00	2·75	2·85	.....	2·90	.....	2·90	2·65	8,120
Potosi, g.s., Nev	.....	.....	·05	.....	·06	.....	.....	.....	·05	·03	·06	·02	4,800
Quicksilver, q., Cal.	4·13	4·10	4·00	3·13	4·25	2·75	4·75	3·25	4·75	4·00	4·25	3·88	60,318
Quicksilver, pref., Cal.	.....	.....	10·75	10·00	10·00	.....	11·50	10·50	10·50	9·75	9·63	9·50	11,540
Savage, s., Nev.	.....	.....	·08	·05	.....	.....	·15	.....	.....	.....	·06	·03	5,400
Sierra Nevada, s., Nev.	·20	.....	.....	.....	·22	·15	·20	.....	·10	.....	·11	·07	13,400
Small Hopes, s.l., Colo.	·70	·60	·65	.....	·50	.....	·55	.....	·45	.....	.....	.....	5,050
Standard Con., g.s., Cal.	3·75	3·10	4·00	2·65	3·55	3·50	4·00	3·00	4·00	3·85	4·00	3·50	9,020
Syndicate, g., Cal.	·08	.....	.....	.....	·06	.....	.....	.....	.....	·07	.....	.....	5,150
Tennessee, c., Tenn.	22·00	17·00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	13,602
Union Con., s., Nev.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	·12	·10	1,200
Union, c., N. C	6·88	4·88	5·75	4·25	5·88	4·00	4·88	4·00	7·25	4·25	5·25	3·75	131,850
Work, g., Colo.	·16	.....	·15	·14	·15	.....	·14	·13	·13	·10	·10	·08	58,300
Yellow Jacket, s., Nev.	·08	.....	.....	.....	.....	.....	·10	.....	.....	.....	·08	.....	4,800
Total sales.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	12,083,195

c., copper; g., gold; i., iron; l., lead; q., quicksilver; s , silver.

steadily until June, when the high mark of $130 was reached, and then declined rapidly, closing at $60·50. The reasons given for the falling off in values were the unsettled conditions in Montana owing to the pending legal suits against the company, the reduction of the dividend-rate, and the cut in copper prices. That the stock should sell at the highest point of the year shortly before the dividend-rate

was reduced may be regarded as evidence of manipulation, or at least, reticence on the part of the management. The dividend-rate was placed on a 4% basis. Anaconda, which is under Amalgamated control, also showed considerable fluctuation, but trading was more limited in volume. The highest price was $54·50 in April and the lowest $28·50 in December. Dividends were reduced from 16% to 10% annually. Tennessee Copper shares have been active, as the company erected an extensive plant on its property, and is working satisfactorily. The stock was traded in on curb, where prices were influenced by the stocks called on change. In April, Tennessee touched high water mark at $28·375, while in December it was down to $9·25. British Columbia Copper was in good request, selling at $22·75 in January, the highest for the year, and at $9 in December. Union of North Carolina, was made active by speculators on curb, who sent prices to $8·25 in April and $3·50 in February, the highest and lowest this year.

The more important gold and silver stocks seldom recorded a large sale and invariably at advancing prices. A notable example is the Homestake in the Black Hills, S. Dak. In 1900 sales of the stock were made at $35@$80, while in 1901 the price advanced to $104, the last sale being reported in September at this figure. This company pays $1,260,000 per year, which is equal to 6% on the capital. Ontario Silver, of Utah, rose to $13 in September, from $6·25 in January, owing to

PRICES OF INDUSTRIAL AND COAL STOCKS AT NEW YORK AND PHILADELPHIA DURING 1901.

Name of Company.	Par Value.	January.		February.		March.		April.		May.		June.	
		H.	L.	H.	L.	H.	L.	H.	L.	H.	L.	H.	L.
American Agri. Chem.	100	.....	.....	30·00	.....	30·00	.....	.....	.....	28·50	.....	30·00	28·00
Am. Ag. Chem., pref.	100	.....	.....	.....	.....	.....	.....	.....	.....	84·25	.....	90·00	84·25
American Alkali	50	2·38	2·00	2·13	1·75	2·25	1·75	2·00	1·25	1·88	1·00	1·13	1·00
American Car & F'd'y.	100	23·88	19·00	23·00	20·25	27·13	20·38	27·50	25·25	29·00	20·00	35·00	28·00
Amer. Car & F'd'y, pref.	100	73·50	67·00	72·13	69·88	82·00	71·50	83·25	78·88	83·00	75·00	89·88	82·38
American Cement	10	8·75	7·50	7·50	7·00	7·25	7·00	7·00	6·88	7·25	6·75	7·25	6·88
Amer. Sm. & Ref.	100	65·50	58·50	63·25	45·63	59·50	51·75	69·00	58·25	61·75	39·75	159·88	55·13
Am. Sm. & Ref., pref.	100	100·00	95·00	99·75	88·00	97·00	90·13	99·00	93·50	98·00	90·00	05·00	97·88
Bethlehem Iron	50	61·00	56·00	61·75	60·38	62·38	61·00	63·00	57·00	63·00	.....	63·00	62·00
Bethlehem Steel	50	19·50	17·00	19·13	18.00	19·50	18·00	24·38	18·00	25·50	19·00	24·50	21·88
Cambria Iron	50	46·00	45·25	46·75	43·50	47·00	45·25	47·00	45·50	47·00	45·50	49·00	43·00
Cambria Steel	50	21·00	16·63	18·38	16·75	18·00	15·75	24·75	16·38	29·75	17·75	35·25	15·50
Colo. Fuel & Iron	100	56·50	41·75	51·50	41·75	55·88	42·13	108·50	55·25	107·50	85·00	36·50	98·00
Colo. H. C. & Iron	100	16·88	14·00	17·50	15·50	20·88	15·25	20·88	17·25	20·00	15·00	25·50	18·75
Monongahela R. Con. C. & C.	100	11·38	10·50	11·00	10·50	13·13	10·63	15·50	13·00	14·75	12·50	15·75	2·50
Mong. R. Coal, pref.	100	43·25	42·50	43·50	42·75	45·88	43·00	49·00	45·75	48·75	40·00	49·00	47·25
National Lead	100	20·50	16·38	19·88	15·50	16·13	15·00	19·50	16·25	23·50	14·13	25·50	19·00
National Lead, pref.	100	92·00	82·00	89·75	82·25	88·00	83·00	85·50	83·00	89·50	79·00	93·88	82·00
National Salt	100	46·00	40·00	44·00	40·00	48·74	42·13	47·00	41·50	46·00	43·00	45·00	43·50
National Salt, pref.	100	79·00	73·00	77·00	74·00	82·38	76·88	81·88	76·00	78·13	75·00	78·25	76·00
Pittsburg Coal	100	28·00	27·13	29·25	27·63	29·25	26·88	35·00	29·00	34·50	31·25	33·00	30·00
Pittsburg Coal, pref.	100	89·00	86·25	88·50	87·13	95·00	88·13	99·00	94·75	97·75	94·75	98·25	94·88
Pressed Steel Car	100	51·88	35·00	39·13	35·50	39·75	30·00	.....	.....	46·50	37·13	46·63	43·75
Republic I. & Steel.	100	18·50	12·88	17·25	13·63	19·13	15·00	22·50	18·75	21·25	15·00	24·00	19·00
Republic I. & S. pref.	100	65·25	55·25	65·00	58·00	75·25	60·65	82·00	74·50	87·00	73·00	78·00	74·50
Sloss Sheffield St. & Iron.	100	22·00	20·00	23·00	19·75	37·00	22·50	41·00	35·00	41·00	32·13	39·00	35·50
Sloss-Sheffield St. & Iron, pref.	100	69·00	65·50	70·50	63·50	79·50	70·50	86·00	78·50	84·50	78·50	83·75	81·00
Standard Oil	100	806·00	785·00	820·00	780·00	805·00	770·00	823·00	797·00	842·00	785·00	800·00	750·00
Susq. Iron & Steel.	10	2·63	.....	2·75	2·13	2·50	2·00	2·50	1·25	2·50	2·00	2·38	2·00
Tenn. Coal, I. & R.R.	100	66·75	52·05	67·75	50·50	62·25	49·38	69·88	62·00	67·00	50·00	76·63	58·00
United Gas Improvement	50	123·00	.....	127·75	122·50	125·25	124·00	126·00	122·50	123·00	113·88	120·75	112·00
United States Steel	100	.....	.....	.....	.....	.....	.....	46·50	.....	54·50	24·00	52·38	47·50
United States Steel, pref.	100	.....	.....	.....	.....	.....	.....	95·75	.....	101·75	69·00	100·38	96·88
Va. Car. Chem	100	.....	.....	.....	.....	.....	.....	71·25	.....	70·00	67·50	68·00	66·25
Va. Car. Chem., pref.	100	.....	.....	.....	.....	.....	.....	122·00	121·00	121·00	117·00	.....	.....
Va. Coal & Coke	100	7·00	3·00	5·00	2·00	5·00	3·00	10·00	3·50	9·00	6·00	10·00	7·50
Total sales		.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

the payment of good dividends. Horn Silver, also of Utah, was strong, selling at higher prices than in 1900, and advancing to $2·25 in October. The dividends this year, amounting to $72,000, are the largest since 1898. Standard Consolidated Gold, of California, has been favored by the continuance of the 10-cent quarterly dividends. The extreme prices were $4·35 in February and $2·65 in August. Brunswick suffered from assessments amounting to 8c. per share, breaking the market from 29c. in March to 6c. in October. Cripple Creek, Colo., stocks were bought chiefly for investment. Portland, which pays 24% annually on its capital of $3,000,000, is closely held, and the small sales made were at $3·35 in January, and $2·30 in March. Elkton, a 13% dividend stock, has fluctuated in price owing to the heavy flow of water in the mine, early in the year, and to the uncovering of a rich chimney of ore in October, which resulted in the payment of an increased quarterly dividend. Isabella was capricious, owing to manipulation in the Western market. Only one quarterly dividend was paid in 1901, as work in the lower levels of the property proved unprofitable; its future depends upon the development of new territory. In February 82c. was paid for the stock, but in December it broke to 30c., with few bids in the market.

The Leadville stocks were handled principally by room traders. Iron Silver

PRICES OF INDUSTRIAL AND COAL STOCKS AT NEW YORK AND PHILADELPHIA DURING 1901.—*Continued.*

Name of Company.	July.		August.		September.		October.		November.		December.		Sales. No. of hares.
	H.	L.	H.	L.	H.	L.	H.	L.	H.	L.	H.	L.	
American Agri. Chem..	32·00	29·00	33·13	25·00	30·00	24·00	25·00	20·00	24·00	22·00	20·00	.....	14.870
Am. Ag. Chem., pref...	90·00	87·00	89·00	.....	85·00	80·00	85·00	80·00	83·00	81·00	81·50	79·50	760
American Alkali	2·38	2·00	2·13	1·75	1·75	·75	·88	·75	·75	·50	·50	·38	118.954
American Car & F'd'y.	33·00	27·00	31·88	27·75	31·00	28·00	29·00	23·75	30·00	25·00	30·63	28·50	211,628
Amer. Car & F'd'y, pf..	89·25	81·25	87·50	80·00	87·38	83·00	83·63	78·00	86·00	80·50	86·50	84·75	32.446
American Cement.....	.....	.....	8·00	7·75	8·00	6·50	6·75	6·50	6·75	6·00	6·50	6·00	28,236
Amer. Sm. & Ref.....	58·00	51·00	55 25	50·00	52·50	43·25	45·00	38.50	47·75	40·75	45·75	42·25	2,180,984
Am. Sm. & Ref., pref. .	104·25	99·50	102·00	99·75	101·00	96·00	98·00	.....	118·75	95·50	97·50	95·50	427,688
Bethlehem Iron.....	57·00	56·75	57·00	56·75	61·00	56·25	72·50	60·75	.....	.....	.....	.....	10.976
Bethlehem Steel.....	16·00	14·50	15·00	14·50	14·50	12·50	.....	.....	.....	.....	.....	.....	232,774
Cambria Iron	44·00	42·75	45·88	44·75	47·00	44·50	47·25	46·50	47·75	47·00	48·00	47·25	12.412
Cambria Steel.....	17·50	15·50	16·88	16·13	25·88	13·50	26·25	25·13	26·75	25·13	25·88	24·38	1,146,082
Colo. Fuel & Iron.....	116·38	90·00	100·00	90·00	104·25	92·75	95·25	88·50	96·00	91·50	92·50	77·00	866,540
Colo. H. C. & Iron.....	23·50	17·50	21·00	19·38	20·00	16·00	17·75	12·50	19·75	14·00	18·75	14·50	179,075
Monongа. R. C. C. & C..	14·25	13·25	14·88	14·00	14·75	13·50	13·75	12·88	13·50	12·88	13·50	12·25	147,244
Mong. R. Coal, pref....	47·50	47·00	47·25	46·50	48·25	47·00	47·00	45·00	46·00	45·00	47·00	45·50	10,579
National Lead.....	23·00	18·00	21·00	19·00	21·00	18·50	21·75	18·13	21·13	18·25	19·00	15·00	179,430
National Lead, pref....	90·50	87·00	90·00	87·00	90·00	87 00	89·75	84·00	89·00	86·00	86·75	74·75	32,504
National Salt.....	45·00	41·50	43·00	40·00	42·50	40·50	40·00	24·00	33·00	29·50	32·00	27·00	108,429
National Salt, pref.....	77·75	74·50	77·00	74·50	77·25	75·50	70·00	61·75	70·00	62·00	69·00	61·00	53,671
Pittsburg Coal.....	32·25	30·13	32·25	30·50	32·88	30·22	30·13	28·00	28·00	27·00	28·25	25·50	170,578
Pittsburg Coal. pref....	97·00	92·50	95·50	93·50	96·13	94·00	95·00	92·50	93·00	91·00	93·00	89·13	75,027
Pressed Steel Car.....	44·75	40·00	43·75	40·50	42·25	39·00	41·50	37·00	45·00	41·50	42·50	37·50	78,340
Republic I. & Steel....	22·25	17·00	21·50	18·50	19·50	11·75	15·63	14·13	16·50	14·63	16·25	14·75	660,847
Republic I. & Steel, pf..	76·63	69·75	76·50	73·00	74·00	60·50	67·00	64·00	70·25	66·00	69·75	66·63	370,176
Sloss-Sheffield St. & I..	35·50	33·00	33·00	30·50	31·50	30·00	30·00	.....	32·00	29·50	31·50	28·00	72,905
Sloss-Sheffield S.&I., pf.	80·75	80·00	80·00	.....	81·00	80·00	80·00	78·00	83·00	77·00	83·00	79·00	17.454
Standard Oil.....	778·00	755·00	780·00	765·00	778·00	735·00	735·00	689·00	722·00	695·00	710·00	659·75	2,105
Susq. Iron & Steel.....	2·50	2·25	2·50	2·25	2·50	1·75	2·00	1·88	2·00	1·75	1·88	1·75	60.145
Tenn. Coal, I. & R.R...	77·50	55·50	68·25	58·00	68·38	59·00	62·00	56·50	66·75	59·25	65·00	58·75	1,458,655
United Gas Improvem't	115·88	111·00	115·50	112·50	116·00	105·00	115·50	113·00	119·00	113·00	118·38	115·00	92,858
United States Steel.....	48·88	37·00	45·75	39·63	45·88	40·25	44·75	41·00	44·50	41·25	43·63	39·63	6,092,906
United States Steel. pf.	99·50	86·00	95·25	89·00	95·75	90·00	98·00	90·13	94·00	90·50	94·00	89·63	3,021,304
Va. Car. Chem.....	65·25	59·00	63·00	58·00	64·00	59·00	61·00	56·75	65·00	59·25	63·00	60·00	15,069
Va. Car. Chem., pref...	125·00	124·00	125·00	120·00	125·00	120·00	125·00	118·00	125·00	121·25	125·00	121·00	4,100
Va. Coal & Coke.....	10·00	9·00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	500
Total sales.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1,848,572

FLUCTUATIONS OF STOCKS AT LONDON DURING 1901.

Name of Company.	Location.	Authorized Capital.	Par Value.	Latest Dividend in 1901.	January-March.	
					H.	L.
		£	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Alaska-Treadwell, g	Alaska	1,000,000	5 0 0	1 6	5 5 0	4 17 6
Anaconda, c	Montana	6,000,000	5 0 0	8 2	9 17 6	8 5 0
De Lamar, g.s	Idaho	400,000	1 0 0	2 0	5 6	2 6
El Oro, g	Mexico	1,000,000	1 0 0	1 6	1 7 6	1 2 6
Hall Sm. & Mg., c.s	British Col	325,000	1 0 0	.....	6 0	4 0
Le Roi, g	British Col	1,000,000	5 0 0	.....	7 12 6	5 17 6
Le Roi No. 2	British Col	120,000	5 0 0	5 0	5 10 0	3 10 0
Lillie, g	Colorado	250,000	1 0 0	.....	12 6	7 6
Montana, g.s	Montana	660,000	1 0 0	.....	32 6	2 0
Mountain Copper	California	1,250,000	5 0 0	5 0	5 5 0	4 12 6
Stratton's Independence, g	Colorado	1,100,000	1 0 0	1 0	2 15 0	1 0 0
Ceplapo, c	Chile	200,000	2 0 0	2 6	3 5 0	1 11 3
Frontino & Bolivia, g	Colombia	140,000	1 0 0	3 0	2 5 0	1 2 6
St. John del Rey, g	Brazil	600,000	1 0 0	1 0	1 6 3	1 0 0
Utah Con., c.g	Utah	300,000	1 0 0	5 0	7 7 6	6 5 0
Ymir, g	British Col	200,000	1 0 0	1 0	1 13 9	1 7 6
Linares, l	Spain	45,000	3 0 0	7 0	9 10 0	6 0 0
Mason & Barry, c.sul	Portugal	420,000	1 0 0	12 6	3 17 6	3 2 6
Rio Tinto, c	Spain	1,625,000	5 0 0	1 15 0	60 7 6	57 2 6
Rio Tinto, pref	Spain	1,625,000	5 0 0	2 6	6 5 0	6 0 0
Tharsis, c	Spain	1,250,000	2 0 0	.....	9 2 6	7 2 6
Assoc. Gold Mines	W. Australia	500,000	1 0 0	.....	3 2 6	2 7 6
Broken Hill Prop., s	N. S. Wales	384,000	8 0	1 0	2 10 0	2 6 0
Great Boulder Prop	W. Australia	175,000	2 0	6	1 14 3	1 1 9
Hannan's Brownhill, g	W. Australia	140,000	1 0 0	.....	4 5 0	3 15 0
Ivanhoe Gold Corp	W. Australia	1,000,000	5 0 0	4 0	8 13 9	6 5 0
Kalgurlie, g	W. Australia	120,000	1 0 0	.....	4 5 0	3 6 3
Lake View Consols, g	W. Australia	250,000	1 0 0	5 0	8 17 6	5 17 6
Mt. Lyell M. & R., l.c	Tasmania	900,000	3 0 0	2 6	5 17 6	4 12 6
Mt. Morgan, g	Queensland	1,000,000	1 0 0	6	5 1 3	4 12 6
Waihi, g	New Zealand	330,000	1 0 0	2 6	11 0 0	8 0 0
Champion Reef, g	Colar Fields	234,169	10 0	4 6	6 3 9	5 12 6
Mysore, g	Colar Fields	265,000	10 0	3 2	6 2 6	5 8 9
Nundydroog, g	Colar Fields	242,000	10 0	1 6	4 8 9	3 1 3
Ooregum, g	Colar Fields	200,000	10 0	1 6	4 13 9	3 13 9
Ooregum, pref., g	Colar Fields	240,000	10 0	1 6	5 15 0	4 17 6
British S. Af. Chartered	South Africa	5,000,000	1 0 0	.....	3 13 9	2 18 9
Cape Copper	South Africa	600,000	2 0 0	5 0	5 15 0	4 17 6
Cape Copper, pfd	South Africa	150,000	2 0 0	5 0	5 10 0	4 7 6
City & Suburban, g	Transvaal	1,360,000	4 0 0	.....	6 0 0	4 12 6
Cons. Deep Level, g	Transvaal	200,000	1 0 0	.....	1 7 6	17 6
Crown Reef, g	Transvaal	120,000	1 0 0	.....	15 15 0	12 10 0
De Beers Cons., d	Cape Colony	3,950,000	5 0 0	1 0 0	32 5 0	28 2 6
Ferreira, g	Transvaal	90,000	1 0 0	.....	21 5 0	18 10 0
Geldenhuis Est., g	Transvaal	200,000	1 0 0	.....	7 2 6	5 7 6
Henry Nourse, g	Transvaal	125,000	1 0 0	.....	9 0 0	7 5 0
Jagersfontein, d	Orange Fr. St.	1,000,000	5 0 0	.....	18 10 0	15 0 0
Johannesburg Con. Invest	South Africa	2,750,000	1 0 0	.....	2 7 6	1 16 3
Jubilee, g	Transvaal	50,000	1 0 0	.....	6 15 0	5 0 0
Langlaagte Est., g	Transvaal	470,000	1 0 0	.....	3 12 6	2 17 6
May Con., g	Transvaal	290,000	1 0 0	.....	4 12 6	3 10 0
Meyer & Charlton, g	Transvaal	100,000	1 0 0	.....	5 12 6	4 5 0
Namaqua, c	Cape Colony	200,000	2 0 0	4 0	5 2 6	4 15 0
Primrose (new), g	Transvaal	300,000	1 0 0	.....	4 11 3	3 7 6
Rand Mines, g	South Africa	1,795,956	4 0	.....	42 10 0	36 12 6
Robinson, g	Transvaal	2,750,000	5 0 0	.....	9 12 6	8 12 6
Sheba, g	Transvaal	1,100,000	1 0 0	.....	1 2 6	16 3
Simmer & Jack Prop., g	Transvaal	5,000,000	5 0 0	.....	6 13 9	5 3 9
Wolhuter, g	Transvaal	860,000	4 0 0	.....	4 17 6	3 11 3

was strong, advancing from $1·10 in April to $2·25 in October. Breece paid three quarterly dividends of 5c. each, and in December distributed 20c., making the year's payment $40,000 larger than in 1900. Consequently little stock was offered for sale, at the extreme prices of $1·70 in June and $1 in November. Alice, of Montana, though it receded from 84c. in January to 37c. in April, showed comparatively small transactions as the property is not yielding according to expectations.

San Francisco Mining Stock Market in 1901.

The record of the San Francisco mining stock market for 1901 shows a marked increased volume of business and wider fluctuations in prices as compared with that of 1900.

FLUCTUATIONS OF STOCKS AT LONDON DURING 1901.—*Continued.*

Name of Company.	April-June.		July-September.		October-December.		Year.	
	H.	L.	H.	L.	H.	L.	H.	L.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Alaska-Treadwell, g.	5 2 6	4 12 6	4 17 6	4 10 0	4 12 6	3 17 6	5 5 0	3 17 6
Anaconda, c.	10 17 6	9 2 6	9 13 9	7 8 9	7 13 6	6 7 6	10 17 6	6 7 6
De Lamar, g.s	5 0	2 6	5 0	2 6	6 0	3 9	6 0	2 6
El Oro, g.	1 8 9	1 6 3	1 8 9	1 2 6	1 10 0	1 6 3	1 10 0	1 2 6
Hall Sm. & Mg., c. s.	10 3	5 3	10 6	7 6	10 0	8 6	10 6	4 0
Le Roi, g.	9 6 3	7 7 6	7 16 3	6 13 9	8 2 6	4 13 9	9 6 3	4 13 9
Le Roi No. 2.	5 15 0	4 0 0	4 5 0	2 15 0	3 15 0	2 6 3	5 15 0	2 6 3
Lillie, g.	7 6	2 6	7 6	1 3	3 9	1 3	12 6	1 3
Montana, g.s.	4 3 3	2 9	4 0	2 6	5 3	4 3	5 3	2 0
Mountain Copper	5 0 0	4 7 6	4 12 6	3 17 6	4 10 0	3 15 0	5 5 0	3 15 0
Stratton's Independence, g.	1 16 3	18 9	1 10 0	1 1 3	1 5 0	18 0	2 15 0	18 0
Copiapo, c.	3 18 9	3 6 3	2 17 6	2 10 0	2 17 6	2 10 0	3 18 9	1 11 3
Frontino & Bolivia, g.	2 5 0	1 13 6	1 17 6	1 0 0	1 1 3	17 6	2 5 0	17 6
St. John del Rey, g.	1 3 9	18 9	1 9 6	19 6	1 3 9	19 6	1 6 3	18 9
Utah Con., c.g.	7 10 0	6 0 0	6 2 6	4 15 0	5 5 0	4 10 0	7 10 0	4 10 0
Ymir, g.	2 3 6	1 8 9	2 12 0	2 1 3	2 5 0	2 1 3	2 12 0	1 7 6
Linares. l.	7 0 0	5 0 0	6 0 0	4 0 0	5 0 0	2 10 0	9 10 0	2 10 0
Mason & Barry, c.sul	4 5 0	3 5 0	3 15 0	3 5 0	3 15 0	3 7 6	4 5 0	3 2 6
Rio Tinto, c.	59 15 0	54 5 0	53 2 6	46 15 0	48 0 0	41 0 0	60 7 6	41 0 0
Rio Tinto, pref.	6 6 3	6 0 0	6 7 6	6 0 0	6 7 6	5 17 6	6 7 6	5 17 6
Tharsis, c.	8 10 0	5 12 6	6 17 6	5 17 6	6 10 0	6 15 0	9 2 6	5 12 6
Assoc. Gold Mines.	2 17 6	2 6 3	2 13 9	2 0 0	2 13 9	2 0 0	3 2 6	2 0 0
Broken Hill Prop., s.	2 7 0	2 3 0	2 0 0	1 15 0	1 19 0	1 11 6	2 10 0	1 11 6
Great Boulder Prop	1 9 0	1 2 9	1 2 0	17 9	1 0 3	18 9	1 14 3	17 9
Hannan's Brownhill, g.	4 11 3	3 15 0	4 8 9	3 8 9	4 0 0	3 3 9	4 11 3	3 3 9
Ivanhoe Gold Corp.	9 13 9	8 12 6	9 3 9	7 10 0	9 3 9	7 11 3	9 13 9	6 5 0
Kalgurlie, g.	4 8 9	3 10 0	3 15 0	3 3 9	3 13 9	3 5 0	4 8 9	3 3 9
Lake View Consols, g.	9 12 6	8 5 0	9 1 3	7 11 3	8 17 6	5 11 3	9 12 6	5 11 3
Mt. Lyell M. & R., l.c.	5 2 6	4 10 0	4 17 6	4 0 0	4 8 9	3 15 0	5 17 6	3 15 0
Mt. Morgan, g.	5 0 0	4 13 9	4 17 6	4 0 0	4 15 0	3 15 0	5 1 3	3 15 0
Waihi, g	8 10 0	5 13 9	5 18 9	5 7 6	5 18 9	5 8 9	11 0 0	5 7 6
Champion Reef, g.	6 6 3	5 15 0	6 1 3	5 10 0	5 18 9	5 11 3	6 6 3	5 10 0
Mysore, g.	6 12 6	5 17 6	6 10 0	5 16 3	6 2 6	5 16 3	6 12 6	5 8 9
Nundydroog, g.	5 12 6	5 1 3	2 3 9	1 18 9	2 16 3	1 18 9	5 12 6	1 18 9
Ooregum, g.	6 7 6	5 15 0	2 15 0	2 10 0	2 16 3	2 7 6	6 7 6	2 7 6
Ooregum, pref. g.	5 12 6	5 5 0	3 5 0	3 1 3	3 5 0	2 16 3	5 15 0	2 16 3
British S. Af. Chartered.	3 11 3	3 1 3	3 5 0	3 0 0	3 0 0	2 10 0	3 13 9	2 10 0
Cape Copper	5 13 9	5 5 0	5 7 6	4 15 0	5 5 0	4 15 0	5 15 0	4 15 0
Cape Copper, pfd.	5 10 0	4 10 0	5 2 6	4 12 6	5 2 6	4 15 0	5 10 0	4 7 6
City & Suburban, g.	6 2 6	5 12 6	6 1 3	5 10 0	6 6 3	5 13 9	6 6 3	4 12 6
Cons. Deep Level, g.	1 7 6	1 0 0	1 5 0	15 0	1 5 0	1 0 0	1 7 6	15 0
Crown Reef, g.	15 15 0	14 10 0	15 2 6	14 0 0	15 10 0	13 7 6	15 15 0	12 10 0
De Beers Cons., d.	34 15 0	32 0 0	36 16 3	33 2 6	39 15 0	36 16 3	39 15 0	28 2 6
Ferreira, g.	22 0 0	20 10 0	21 0 0	19 0 0	21 0 0	18 15 0	22 0 0	18 10 0
Geldenhuis Est., g.	6 17 6	6 7 6	6 11 3	5 17 6	6 16 3	5 15 0	7 2 6	5 7 6
Henry Nourse, g.	8 15 0	8 2 6	8 10 0	7 17 6	8 15 0	7 15 0	9 0 0	7 5 0
Jagersfontein, d.	19 10 0	16 10 0	19 5 0	15 10 0	22 12 6	18 17 6	22 12 6	15 0 0
Johannesburg Con. Invest.	2 6 3	2 2 6	2 6 3	2 0 0	3 7 6	2 1 3	3 7 6	1 16 3
Jubilee, g.	6 10 0	5 15 0	6 2 6	5 7 6	5 17 6	5 6 0	6 15 0	5 0 0
Langlaate Est., g.	3 10 6	3 5 0	3 12 6	3 2 6	3 10 0	2 1 3	3 12 6	2 1 3
May Con., g.	4 13 9	4 5 0	4 7 6	4 1 3	4 10 0	3 5 0	4 13 9	3 5 0
Meyer & Charlton, g.	6 0 0	5 7 6	5 12 6	4 17 6	5 17 6	4 1 3	6 0 0	4 1 3
Namaqua, c.	5 12 6	4 2 6	4 11 3	4 0 0	4 7 6	3 17 6	5 12 6	3 17 6
Primrose (new), g.	4 7 6	4 1 3	4 5 0	3 17 6	4 3 9	3 13 9	4 11 3	3 7 6
Rand Mines, g.	42 15 0	41 15 0	42 17 6	40 2 6	40 11 3	9 17 6	42 17 6	9 17 6
Robinson, g.	9 17 6	9 10 0	9 16 3	8 15 0	9 18 9	8 17 6	9 18 9	8 12 6
Sheba, g.	1 3 9	1 0 0	1 1 3	17 6	1 0 0	16 3	1 3 9	16 3
Simmer & Jack Prop., g.	6 8 9	6 5 0	6 8 9	6 0 0	6 16 3	5 16 3	6 16 3	5 3 9
Wolhuter, g.	4 17 6	4 2 6	4 12 6	3 17 6	4 7 6	3 15 0	4 17 6	3 11 3

c., copper ; d., diamonds ; g., gold ; l., lead ; .s, silver.

The improved facilities inaugurated and installed on the Comstock Lode during the preceding years, by which the drainage of the lower levels of the mine was to be accomplished, and electric hoists, etc., installed, for a more thorough exploitation of the ore bodies which were believed to exist in these lower levels, stimulated expectations of a great revival of business in Comstock mining stock. Although these hopes and expectations were not fully realized, yet the moderate revival that occurred during 1901 gave a new interest and activity to the market such as it had not felt for several years.

The history of the San Francisco mining stock market for some years past has been marked by extreme fluctuations, a sudden upward movement in one or two

stocks would carry prices skyward, inspiring fresh hopes in the breasts of long disheartened, assessment-paying stockholders. But this sporadic movement would last scarcely a week, and would be followed by a long period of dullness, with renewed assessments to depress the shareholders. Other booms would follow, and history would repeat itself as above. In these movements prices rarely rose above the dollar mark, and it is now nearly ten years since Comstock mining stock reached $10 per share, and more than five years since any stock sold as high as $5.

The confidence in the future of the Comstock lode has been further strengthened by the payment during 1901 of three dividends aggregating $75,000, the balance going into improvements by the Consolidated California and Virginia; the abandonment of former expensive methods of mining and milling and the substitution of more efficient plants, making the large bodies of low-grade ore, formerly neglected, available; the successful work of the Davis-Calyx drill, which, by penetrating the Potosi-Brunswick ground for a depth of 800 ft., demonstrated the occurrence of paying ore bodies in unexplored ground, and the extension of the south lateral of the Comstock tunnel through the Silver City country, which will drain the Holman property of the Silver Hill Mining Co., already demonstrated to be valuable. With the new improvements under way and large bodies of low-grade ore ready for the mills, the future of the Comstock is full of bright promise.

DIVIDENDS PAID BY AMERICAN MINES AND INDUSTRIAL COMPANIES, $1=$1,000; TOTAL, FULL AMOUNT.

Name of Company.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	Total Paid.
Aberdeen, c., N. M.									$32	$32,175
Acacia, g., Colo.								$45		45,000
Adams, s.l., Colo.			$6					8	15	710,000
Ætna Con., q., Cal.		$20	20	$40	$40	$40	$60	15		235,000
Ala. Con. Coal & I., pf., Ala.							44	175	175	393,750
Alamo, g, Utah							3			2,500
Alaska Goldfields, Alaska.							125		135	260,000
Alaska-Mexican, g., Alaska.		120	90	80	90	72	72	72		465,381
Alaska-Tread. g., Alaska.	$375	375	400	350	300	300	300	300	300	4,820,000
Alliance, g., Colo.							32			31,500
Allis-Chalmers, pf.									569	569,750
Alpha Oil, Cal.									1	1,250
Altoona Coal & Coke, Pa.									75	75,000
Amalgamated, c., Mont.							1,500	6,000	8,304	15,809,491
Amanda, g., Colo.								10		10,000
Amazon, g., Colo.								102		121,882
American, g.s.l., Colo.						36	54	60		446,000
American Agric. Chem., pref.							510	1,020	1,025	2,554,590
American Cement, Pa.							60	80	160	300,000
American Coal, Md.		98	105	120	120	135	150	255	150	1,132,500
American Fuel Oil, Cal.							3	12	1	16,000
Am. Iron & Steel, com.								34	19	484,100
Am. Iron & Steel, pref.							50	150	150	312,500
Am. Sm. & Ref., pref.							1,137	1,545	2,709	5,391,553
American Steel & Wire, com.								2,625	1,500	4,125,000
American Steel & Wire, pref.							2,800	2,800	1,400	7,000,000
American Steel Hoop, pref.							245	980	490	1,715,000
American Sheet Steel, pf.									858	857,500
Am. Zinc-Lead Sm., Mo.							120	60		180,000
Anaconda, c., Mont.						3,000	3,900	4,800	3,900	20,850,000
Anchoria-Leland, g., Colo.				30	72	72	36			198,000
Anderson, g., Colo.								15		15,000
Anglo-Mexican, g., Mexico.			361	271	90	180	180			1,925,048
Apollo Con., g., Alaska.					100		40	70		110,000
April Fool, g., Nev.							16			16,000
Argentum-Juniata, s., Colo.			156				42			198,000
Argonaut, g., Cal.						180	240	70		490,000
Arizona, c.s., Ariz.						405	722	576	866	2,330,669
Arizona Western Oil, Cal.								6		6,000
ssociated, g., Colo.						50	12			12,000
tlantic, c., Mich.					40	40		80	80	940,000

DIVIDENDS PAID BY AMERICAN MINES AND INDUSTRIAL COMPANIES.—*Continued.*

Name of Company.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	Total Paid.
Bald Butte, g., Mont.	$49	$172	$127	$38	$33	$98	$150	$33	$180	$1,102,148
Bethlehem Steel, Pa.							300	600	425	1,325,000
Big Four, g., Colo.								15		15,000
Bonanza Dev., g., N. Mex.							1,050			1,050,000
Boston, q., Cal.							20			20,000
Boston & Colo. Sm., Colo.							56	34	45	360,100
Boston-Aurora, z., Mo., pref.							29	37		66,160
Boston-California, g., Cal.							72			72,000
Boston-Duenweg, z., Mo.							32	24		56,000
Boston Get There, z., Mo.							11	9		20,250
Boston Gold-Cop. Sm., Colo.								50	100	150,000
Boston-Little Circle, z., Mo.							75	13	25	112,500
Boston & Montana, c.s., Mont.		275	1,050	1,500	1,800	1,950	5,375	6,450	5,250	26,225,000
Boston-Phila., z.l., Kas.								2		2,000
Boston-Providence, z., Mo.							11	6		17,242
Boston-S. Dak., g., S. Dak.								10		10,000
Boston-Springfield, z., Mo.								15		15,000
Boston-Sunflower, z. Mo.							5			4,500
Breece, l.s., Colo						10	40	30	70	170,000
Buckeye, g., Colo.								160		160,000
Buckhorn Oil, Cal.								4	4	3,800
Buffalo Hump, g., Idaho.								275	25	300,000
Bull Hill, Con., g., Colo.								15	38	37,500
Bull'n-Beck & Cham., g.s., Ut'h.		425	325	290	170	90	120	60		2,498,400
Bunker Hill & Sull., s.l., Ida.					102	228	201	252	252	1,305,000
Burlington Oil, Cal.								3		3,600
Butte & Boston, c.s.l., Mont.								1,000	600	1,600,000
California Oil & Gas, Cal.									540	540,000
Calumet & Hecla, c., Mich.	2,000	1,500	2,000	2,500	5,000	5,000	10,000	7,000	4,500	77,350,000
Cambria Iron, Pa.							339	339	339	1,015,960
Cambria Steel, Pa.							660	940	2,150	3,750,000
Cariboo-McKinney, g., B. C.			49	76	48	67	72	86		478,087
Cent'l-Eureka, s.g.l., Utah.	188	195	510	390	98	15	120	268	200	2,617,700
Center Creek, l.z., Mo.							10	30	20	60,000
Center Star, g., B. C.								35	175	210,000
Central, l., Mo.					28	54	60	65	60	267,000
Central Oil, Cal.								73	25	98,000
Central Oil, W. Va.								23	63	86,000
Champion, g., Cal.	41	41	27		51	26	35			321,700
Charleston, phos., S. C.						30	20			50,000
Cloverdale, z., Mo.							40	40		80,000
Colonial, l., Mo.							10			10,000
Colorado Fuel & Iron, com.									662	637,500
Colo. Fuel & Iron, Colo., pref.	1,208	160		160	80			800	160	1,320,000
Columbia, l., Mo.								12		12,125
Commodore, g., Colo.					20	20	48			432,000
Commonwealth, z., Mo., pref.							20	30		50,000
Consolidated, g., Colo.							10	110	182	302,000
Consolidated, z.l., Mo., pref.								8		8,000
Consolidation Coal, Md.	205	205	205	205	205	205	205	205	205	5,318,000
Con. Mercur, g., Utah.	60	200	200	200	250	355	100	225		1,591,000
Con. Mercur, g. (new), Utah.									375	485,000
Cordell, z l., Mo.							8	27		80,000
Cripple Creek Con., g., Colo.								160		160,000
Crœsus, g., Cal.						29	19	104	76	227,300
Crowned King, g.s.l., Ariz.						96	121			242,760
Crucible Steel, pref., U. S.								427	1,740	12,187,500
Daly-West, s.l.g.c., Utah.							120	487	600	1,207,500
Deer Trail Con., g., Wash.							55			55,000
De Lamar, s.g., Idaho.	450	500	450	500		48	48	48	192	2,586,000
Delta, l.z., Mo.							8	4		7,680
Denver & Cripple C'k, g., Colo.								11		10,625
Desloge Con., l., Mo.						20	30	20		70,000
Dewey Con., Utah.								2	3	5,850
Diamond Star Oil, Cal.								6		6,000
Diamond State St., com., Del.								100	64	184,000
Dixie, g., Utah.								10	158	167,500
Doe Run, l., Mo.					30	30	60	60	60	477,072
Dominion Coal, N. S.									240	1,920,000
Dominion I & St., pf., N. S.									175	175,000
Ducktown Sul., C. & I., Tenn.						29	86			175,000
Eldorado, g., Cal.							10			10,000
Elkton Con., g., Colo.		66		90	260	220	68	259	325	1,304,461
Empire State, g.s.l., Idaho.						67	256	355	586	1,258,338
Empire Steel & Iron, pref.							71	107	71	248,850
Fanny Rawlings, g., Colo.							20			20,000
Favorite, g., Colo.								48		48,000
Federal Steel, com.								1,743	2,324	4,067,376
Federal Steel, pref.							1,598	5,060	2,397	9,089,554
Ferris-Haggerty, c., Wyo.							5		10	15,000
Flat-Top C. Land Ass'n, com.								111	74	352,840
Flat-Top C. Land Ass'n, pref.								149	149	2,098,450
Florence, s., Mont.			35	54	54	44	44	20		223,780

DIVIDENDS PAID BY AMERICAN MINES AND INDUSTRIAL COMPANIES.—*Continued.*

Name of Company.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	Total Paid.
Frisco Con., l.s., Ida.	.....	$15	$10	$50	.....	.....	$165	.....	.....	$980,000
Garfield Con., g., Colo.	.....	.....	.....	.....	.....	.....	34	.....	$125	159,000
Gemini, g., Utah	.....	.....	.....	.....	.....	.....	.....	$50	.....	700,000
General Chem., com	.....	.....	.....	.....	.....	.....	129	265	287	700,988
General Chem., pref.	.....	.....	.....	.....	.....	.....	390	494	506	1,271,884
Gold Belt Con., g., Colo.	.....	.....	.....	.....	.....	.....	.....	113	.....	112,500
Gold Deposit, g., Colo.	.....	.....	.....	.....	.....	.....	.....	10	.....	10,000
Gold Coin of Victor, Colo.	.....	.....	.....	.....	$120	$120	210	240	360	960,000
Golden Cycle, g., Colo.	.....	.....	.....	.....	60	60	105	120	30	408,500
Golden Eagle, g., Colo.	.....	.....	.....	10	.....	.....	10	5	10	98,916
Golden M. & Ext., g., Ont.	.....	.....	.....	.....	.....	.....	10	.....	.....	10,000
Golden Star, g., Ont.	.....	.....	.....	.....	.....	.....	46	.....	.....	45,500
Gold King, g., Colo.	.....	.....	.....	11	25	.....	66	112	56	412,219
Grafton, g., Colo.	.....	.....	.....	.....	.....	.....	10	.....	.....	10,000
Grand Central, g., Utah.	.....	.....	.....	.....	.....	219	348	25	.....	691,250
Grand Gulch, c., Ariz.	.....	.....	.....	.....	.....	.....	.....	10	.....	9,600
Grass Valley Expl., g., Cal.	.....	.....	.....	.....	.....	.....	23	7	.....	30,000
Gray Eagle Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	50	97	217,000
Greater Gold Belt, g., Colo.	.....	.....	.....	.....	.....	.....	.....	76	.....	76,000
Great Western Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	10	.....	10,000
Gwin, g., Cal.	.....	.....	.....	.....	16	35	35	66	120	271,500
Hecla, l.s., Ida.	.....	.....	.....	.....	.....	.....	.....	100	.....	100,000
Hecla Con., s.l., Mont.	$60	120	90	45	30	.....	15	50	30	2,250,000
Helena, g., Oregon	.....	.....	.....	.....	.....	.....	.....	45	72	116,500
Helena & Liv., S. & R., Mont.	.....	.....	.....	.....	.....	.....	.....	90	.....	90,000
Hidden Treasure, g., Cal.	.....	.....	.....	.....	.....	.....	.....	29	.....	457,452
Holy Terror, g., So. Dak.	.....	.....	.....	.....	36	81	50	5	.....	172,000
Home, g., Colo	.....	.....	.....	.....	.....	.....	.....	100	137	237,500
Hone Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	200	61	260,000
Homestake, g., So. Dak.	150	256	344	375	375	656	963	1,260	1,260	10,668,750
Homestake Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	23	12	81,500
Horn Silver, g.s.l.z.c., Utah.	230	150	50	50	.....	80	20	20	72	5,342,000
Idaho, g., B. C.	.....	.....	.....	.....	.....	.....	28	.....	.....	292,000
Idaho, g., Ida.	.....	.....	.....	.....	.....	.....	.....	8	.....	8,188
Independence Con., g., Colo.	.....	.....	.....	.....	.....	.....	.....	100	181	281,375
Iowa, g.s.l., Colo.	.....	.....	.....	50	25	10	.....	39	67	203,501
Iron Silver, s.l., Colo	.....	.....	.....	.....	.....	.....	.....	50	.....	2,550,000
Isabella, g., Colo.	.....	.....	23	180	68	.....	270	158	23	742,500
Jack Pot, g., Colo.	.....	.....	.....	.....	.....	.....	175	.....	.....	175,000
Jackson, g., Cal.	.....	.....	2	.....	.....	.....	.....	6	.....	6,000
Jamison, g., Cal.	.....	.....	.....	.....	.....	.....	12	.....	12	62,400
Jeff. & Clearf. Coal, Pa., com.	.....	.....	.....	.....	.....	.....	.....	30	30	30,000
Jeff. & Clearf. Coal, Pa., pref.	.....	.....	.....	.....	.....	75	75	75	75	450,000
Kentucky I. & Coal, Ky.	.....	.....	.....	.....	.....	.....	11	.....	.....	164,061
Kern Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	375	25	350,000
Kern River Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	10	.....	10,000
La Fortuna, g., Ariz.	.....	.....	.....	.....	188	238	238	238	150	1,066,000
Lake City, g., Colo.	.....	.....	.....	.....	.....	.....	.....	4	.....	3,575
Lake Superior, i., Mich.	.....	.....	84	.....	.....	263	84	.....	.....	2,132,000
Last Chance, g., B. C.	.....	.....	.....	.....	.....	20	25	.....	.....	45,000
Last Dollar, g., Colo.	.....	.....	.....	.....	.....	.....	30	90	60	180,000
Lawrence, g., Colo.	.....	.....	.....	.....	.....	.....	.....	10	.....	10,000
Lehigh Coal & Nav., Pa.	646	574	574	574	574	574	574	789	861	19,377,788
Le Roi, g., B. C.	.....	.....	.....	.....	.....	.....	240	.....	.....	1,305,000
Lightner, g., Cal.	.....	.....	.....	.....	.....	.....	.....	10	18	28,117
Lillie, g., Colo.	.....	.....	.....	.....	.....	50	136	45	.....	349,188
Madison, g., Colo.	.....	.....	.....	.....	.....	.....	.....	35	.....	35,000
Magnolia, g., Colo.	.....	.....	.....	.....	.....	.....	.....	187	.....	187,000
Mammoth, g.s.c., Utah.	.....	.....	.....	100	.....	200	260	200	100	1,840,000
Marion Con., g., Colo	.....	.....	.....	.....	.....	.....	5	.....	.....	200,000
Maryland Coal, Md., pref.	47	66	85	94	75	85	94	94	104	744,544
Mary McKinney, g., Colo.	.....	.....	.....	.....	.....	.....	30	150	150	330,000
Midget, g., Colo.	.....	.....	.....	.....	.....	.....	.....	25	15	165,000
Mo. Zinc Fields, Mo., pref.	.....	.....	.....	.....	.....	.....	21	11	.....	31,865
Modoc, g., Colo.	.....	.....	.....	.....	10	90	45	60	35	225,000
Monarch, g., Colo	.....	.....	.....	.....	.....	.....	.....	120	.....	120,000
Monongahela R. C. & C., Pa., pref.	.....	.....	.....	.....	.....	.....	.....	700	694	1,388,600
Montana Coal & Coke, Mont.	.....	.....	.....	.....	.....	.....	.....	120	.....	120,000
Montana, g.s., Mont.	.....	.....	205	.....	.....	36	99	.....	.....	453,710
Montana Ore Purchas., Mont.	.....	.....	160	320	160	160	560	240	792	2,392,000
Monument, g., Colo.	.....	.....	.....	.....	.....	18	6	.....	3	21,124
Morning Star, g., Cal.	.....	.....	.....	.....	.....	82	62	7	.....	854,400
Morse, g., Colo.	.....	.....	.....	.....	.....	.....	15	.....	.....	215,650
Mountain, c., Cal.	.....	.....	.....	.....	31	62	1,080	1,200	720	3,093,750
Mount Diablo, s., Nev.	.....	.....	.....	.....	.....	.....	.....	5	.....	260,271
Mount Rosa, g., Colo.	.....	.....	.....	5	10	20	40	.....	.....	75,000
Mount Shasta, g., Cal.	.....	.....	.....	.....	.....	.....	6	.....	.....	6,000
Napa Con., q., Cal.	70	50	80	70	80	80	110	40	40	1,140,000
National Lead, com.	298	447	149	.....	.....	149	149	149	.....	1,341,498
National Lead, pref.	1,341	1,490	1,192	1,043	1,043	1,043	1,043	1,043	1,043	11,863,560
National Salt, com.	.....	.....	.....	.....	.....	.....	.....	245	420	615,000
National Salt, pref.	.....	.....	.....	.....	.....	.....	175	350	350	875,000
National Steel, pref.	.....	.....	.....	.....	.....	.....	1,418	1,891	945	4,252,500

DIVIDENDS PAID BY AMERICAN MINES AND INDUSTRIAL COMPANIES.—*Continued.*

Name of Company.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	Total Paid.
National Tube, com	.....	.....	.....	.....	.....	.....	.....	$1,196	$1,196	$3,391,684
National Tube, pref	.....	.....	.....	.....	.....	.....	$700	2,800	2,800	6,299,416
New Central Coal, Md	$50	$50	.....	.....	.....	$20	40	40	.....	510,000
New Idria, q., Cal	.....	.....	.....	.....	$10	70	110	60	70	330,000
N. J. & Mo., s., Mo	.....	.....	.....	.....	.....	.....	.....	11	.....	11,000
N. J. Zinc	.....	.....	.....	.....	600	600	600	1,000	400	8,200,000
N. Y. & Hond. Ros., s.g., C.A	.....	.....	.....	.....	165	165	180	255	240	1,070,000
Nighth'k & Nig't'gale, g., Colo	.....	.....	.....	.....	.....	.....	.....	180	.....	180,000
North Star, g., B. C	.....	.....	.....	.....	.....	.....	.....	39	.....	39,000
North Star, g., Cal	.....	.....	.....	.....	.....	.....	50	.....	.....	584,850
Oceanic Oil, Cal	.....	.....	.....	.....	.....	.....	.....	2	.....	2,000
Old Colony, Z. & Sm., Mo	.....	.....	.....	.....	.....	.....	.....	68	70	138,184
Olive, g., Ont	.....	.....	.....	.....	.....	.....	12	.....	.....	12,000
Omega, g., Colo	.....	.....	.....	.....	.....	.....	.....	18	.....	18,188
Ontario, s., Utah	.....	.....	.....	$180	280	.....	15	90	90	14,737,000
Original-Empire, g., Cal	.....	.....	.....	.....	.....	.....	100	.....	.....	530,000
Osceola, c., Mich	100	.....	$100	125	191	277	558	558	575	4,245,800
Pacific Coast Borax, Cal	.....	.....	.....	.....	.....	.....	100	240	200	971,500
Park Oil, Cal	.....	.....	.....	.....	.....	.....	.....	5	.....	4,897
Parrot, c.s., Mont	138	67	.....	.....	.....	488	1,242	1,084	1,264	5,658,000
Payne, g., B. C	.....	.....	.....	.....	.....	.....	50	.....	78	1,498,000
Pennsylvania Coal, Pa	800	1,000	800	1,500	800	800	800	800	2,160	21,860,000
Pennsylvania Con., g., Cal	.....	.....	.....	.....	.....	28	68	26	.....	161,335
Penn. Salt Mfg., Pa	.....	.....	.....	.....	.....	150	150	300	300	12,850,000
Pennsylvania Steel, Pa	.....	.....	.....	.....	.....	.....	26	105	1,068	1,198,750
Penoles, s.l., Mex	.....	.....	.....	.....	.....	.....	.....	.....	698	1,350,550
Petro, s., Utah	.....	.....	.....	.....	.....	.....	15	.....	.....	32,000
Philadelphia, Natural Gas, pref	.....	.....	.....	.....	.....	.....	.....	100	200	399,886
Pioneer, g., Cal	.....	.....	.....	.....	.....	50	13	.....	.....	62,500
Pittsburg Coal, Pa	.....	.....	.....	.....	.....	.....	.....	2,240	2,079	4,158,168
Plumas-Eureka, g., Cal	51	51	51	25	25	.....	.....	84	34	2,831,294
Portland, g., Colo	.....	67	556	240	330	570	720	750	720	4,027,080
Producers & Cons. Oil, Cal	.....	.....	.....	.....	.....	.....	.....	53	4	56,500
Queen Bess Propr., g., B. C	.....	.....	.....	.....	.....	.....	25	.....	.....	25,000
Quicksilver, q., Cal	.....	.....	.....	.....	.....	.....	22	22	22	1,866,411
Quincy, c., Mich	300	400	600	1,000	800	650	950	900	900	12,870,000
Rambler-Cariboo Con., g., B.C	.....	.....	.....	.....	.....	.....	31	34	735	735,000
Raven, g., Colo	.....	.....	.....	.....	.....	20	50	50	25	120,000
Republic Con., g., Wash	.....	.....	.....	.....	.....	120	158	105	.....	383,500
Republic I. & St., pref	.....	.....	.....	.....	.....	.....	355	1,421	1,421	3,198,338
Reward, g., Cal	.....	.....	.....	.....	.....	.....	20	.....	.....	90,000
Rex Oil, Cal	.....	.....	.....	.....	.....	.....	.....	21	.....	21,250
Rocco-Homestake-Nev., s.g.l	.....	.....	.....	.....	.....	.....	.....	9	45	54,000
Rocky Gulch, g., Oregon	.....	.....	.....	.....	.....	.....	.....	25	.....	25,000
Russell Irwin, z., Mo	.....	.....	.....	.....	.....	.....	15	.....	.....	15,000
Sacramento, g.s.l., Utah	.....	.....	.....	15	15	60	50	.....	15	183,000
Saint Joseph, l., Mo	150	150	150	.....	144	150	150	150	150	3,459,500
Santa Rita, g., Colo	.....	.....	.....	.....	.....	.....	.....	4	.....	4,000
Shelby Iron, Ala	.....	.....	.....	.....	.....	.....	130	120	.....	250,000
Silver King, g.s.l., Utah	.....	.....	263	375	450	450	625	1,000	1,300	4,750,000
Silver Shield, g.s.l., Utah	.....	.....	.....	.....	.....	.....	.....	2	3	4,500
Six Points, g., Colo	.....	.....	.....	.....	.....	.....	.....	120	.....	180,000
Sloss-Sheff. I. & St., pref	.....	.....	.....	.....	.....	.....	.....	456	467	922,414
Small Hopes, s., Colo	.....	.....	.....	.....	.....	25	25	.....	.....	3,325,000
Smuggler, s.l.z., Colo	575	50	.....	110	.....	120	275	360	360	2,155,000
Southern Boy, g., Colo	.....	.....	.....	.....	.....	.....	.....	18	.....	17,500
Southern Cal. Oil & Fuel, Cal	.....	.....	.....	.....	.....	.....	.....	3	33	39,000
South Swansea, g.s.l., Utah	.....	.....	.....	20	50	38	53	.....	8	167,500
Specimen, g., Colo	.....	.....	.....	.....	.....	.....	.....	153	.....	153,347
Squaw Mountain, g., Colo	.....	.....	.....	.....	.....	.....	10	.....	.....	10,090
Standard, s.l., Idaho	.....	.....	.....	.....	.....	.....	.....	320	300	2,465,000
Standard Con., g., Cal	20	40	20	.....	40	27	60	71	71	4,035,458
Standard Oil of N. J	.....	.....	.....	.....	.....	.....	26,325	47,800	46,660	120,885,000
Stratton's Independ., g., Colo	.....	.....	.....	.....	.....	.....	976	1,789	788	3,552,856
Strong, g., Colo	.....	.....	.....	.....	.....	250	300	300	300	1,345,000
Susquehanna I. & St., Pa	.....	.....	.....	.....	.....	.....	180	113	68	582,500
Swansea, s.l., Utah	.....	.....	.....	20	50	65	65	75	29	330,500
Tamarack, c., Mich	600	400	400	500	360	440	600	1,020	1,200	8,490,000
Temoni, g., Colo	.....	.....	10	.....	.....	.....	.....	250	.....	250,000
Tenn. C., I. & R. R., com	.....	.....	.....	.....	.....	.....	.....	451	.....	1,102 144
Tenn. C., I. & R. R., pref	.....	.....	.....	.....	.....	.....	.....	189	20	208,880
Texas & Pacific Coal, Tex	.....	.....	.....	.....	.....	.....	140	120	120	1,220,000
Tomboy, g., Colo	.....	.....	300	300	.....	50	152	144	216	1,172,000
Touraine, g., Colo	.....	.....	.....	.....	.....	.....	.....	88	9	96,119
Union, g., Colo	.....	.....	27	13	23	.....	.....	313	25	430,344
Union, z.l., Kas	.....	.....	.....	.....	.....	.....	.....	9	7	16,000
United, z.l., Mo	.....	.....	.....	.....	.....	.....	3	28	30	60,259
United States Crude Oil, Cal	.....	.....	.....	.....	.....	.....	.....	3	24	27,290
U. S. Oil, W. Va	.....	.....	.....	.....	.....	.....	300	275	.....	575,000
United Verde, c., Ariz	435	.....	.....	.....	.....	.....	3,000	4,499	.....	.....
Utah, g., Utah	5	.....	17	22	4	.....	2	2	2	12,000
Vindicator, g., Colo	.....	.....	.....	.....	.....	138	178	189	170	664,000
Va.-Car. Chem., com	.....	.....	.....	10	40	40	270	360	480	1,650,000

DIVIDENDS PAID BY AMERICAN MINES AND INDUSTRIAL COMPANIES.—*Concluded.*

Name of Company.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	Total Paid.
Va.-Car. Chem., pref.							$800	$800	$800	$5,100,000
Warwick Iron & Steel, Pa.							64	122	84	270,284
War Eagle, g., B. C.						$177	315	53		545,250
Weatherly-Bonanza, g., Wash.							2			2,000
West Lake Oil, Cal.								50		50,000
Westmoreland Coal							750	750	750	6,750,000
What Cheer, z., Mo.							2	9		11,250
Wolverine, c., Mich.						60	210	240	240	753,000
Wythe, Lz., Va.								76		76,000
Yellow Aster, g., Cal.						$40	131	145	150	459,410
Ymir, g., B. C.								30		290,000
Yreka, g., Cal.									50	58,000
Yukon Oil, Cal.								3	18	21,000
Zoe, g., Colo.									8	7,500

c., copper; g., gold; i., iron; l., lead; q., quicksilver; s., silver; z., zinc.

ASSESSMENTS LEVIED BY MINING COMPANIES.

Name of Company.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	Total Levied.
Acorn, g.s.l., Utah							$365	$760		$1,125
Ætna, g.s.l., Idaho								5,000		5,000
Ætna, g.s.l., Utah						$2,500	500			3,000
Alaska, g.s.l., Utah							34,000	20,000	$12,000	66,000
Alexandria, g.s.l., S. Dak							500	500		1,000
Alhambra, s., Nev.						100,000				100,000
Alliance Explor. & Mg., g., Cal.								5,000	2,000	7,000
Alliance, g., Utah			$50,000				15,000	10,000		225,000
Allison-Rauch-Ford, g., Cal.							5,000	10,000		15,000
Allouez, c., Mich.		$16,000				80,000			240,000	1,760,280
Alpha, s., Nev.	$10,000	6,000	15,750	$15,750	$8,400	8,400	3,150	3,150	3,150	285,500
Alta, s., Nev.	25,200	50,400	20,160	32,400	16,200	16,200	16,200	16,200	10,800	3,708,110
Alta, g., Utah							938			938
Amelia, g., Cal.								2,500		2,500
Andes, s., Nev.		25,000	15,000	15,000	20,000	10,000	15,000	15,000	10,000	1,235,000
Annie, g.s., Utah								5,000		5,000
Arnold, c., Mich.						180,000				180,000
Arrastraville, g., Cal.						20,000	20,000	10,000		50,000
Badger, g., Oregon								10,000	10,000	20,000
Badger Hill & Cher'kee, g., Cal.							60,000			60,000
Baliol, g., Cal.					25,000	30,000				55,000
Belcher, s., Nev.		50,200	50,200	50,200	57,000	20,800	36,400	52,000	52,000	3,655,200
Belle, g., Cal.								2,000		2,000
Bellefountaine, g.s., Cal.						10,000	10,000	10,000	10,000	40,000
Ben Butler, g.s., Utah							11,250	6,250	2,500	20,000
Benton Con., g.s., Nev.								20,000		20,000
Best & Belcher, s., Nev.	75,600	50,400	50,400	25,200	75,600	30,240	40,320	60,480	30,240	2,722,128
Biesinger & Beck, s.l.g., Utah								756		756,000
Bingham Placer, g., Utah							27,500	27,500		55,000
Blue Bird, g., Utah							500			500
Blue Gravel, g., Cal.								10,000		10,000
Boston & Cripple C'k, g., Colo.						20,000				20,000
Boulder, g., Cal.						10,000	3,000	3,000	3,000	19,000
Bountiful, g.s., Utah								5,000		5,000
Brunswick Con., g.s., Cal.	20,000	10,000	20,000	15,000	30,000		15,000	50,000	40,000	265,000
Buchanan, g., Cal.						25,000				25,000
Buckeye, g., Utah				3,750	6,250	6,250				16,250
Buffalo Hump Dev., g., Wash.								200		200
Bullion, s., Nev.	25,000	30,000	40,000	20,000	20,000	15,000	10,000	5,000	6,000	3,141,000
Bunker Hill, g.s., Utah							5,000	6,250		11,250
Cadmus, g., Cal.								10,000		10,000
Caledonia, s., Nev.		50,000		5,000				30,000	15,000	3,285,000
California, g., Cal.			4,500		1,000		2,000		2,000	21,500
California Borax, Cal.								9,500		13,000
California Dredging, Cal.									30,000	30,000
California Mutual Oil, Cal.									12,500	12,500
California Oil, Cal.									20,000	20,000
Canadian King, Wash.									1,000	1,000
Canton Placer, g., Cal.										25,000
Carbon Oil, Cal.										8,000
Caribou Oil, Cal.									16,000	24,000
Carmelita Oil, Cal.									10,000	10,000
Casas Oil, Cal.									2,000	2,000
Cedar Creek, g., Cal.						2,000				2,000
Centennial, c., Mich.					120,000	300,000		270,000	180,000	910,000
Central Eureka, g., Cal.					20,000			12,000		32,000
Central Mammoth, g., Utah								500		500
Challenge Con., s., Nev.	15,000	50,000	5,000	7,500	5,000	10,000	12,500	22,500	5,000	462,500
Century Oil, Cal.									8,600	17,200

ASSESSMENTS LEVIED BY MINING COMPANIES.—*Continued.*

Name of Company.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	Total Levied.
Cerulean, g., Cal.	.....	.....	.....	.....	.....	.....	.....	.....	$5,000	$5,000
Channel Bend, g., Cal	.....	.....	.....	.....	.....	$2,000	.....	.....	.....	2,000
Chicago & Mercur, g.s., Utah	.....	.....	.....	.....	.....	.....	$1,000	.....	1,000	2,000
Chollar, s., Nev	$61,600	$56,000	$56,000	$28,000	$44,800	50,400	28.000	$39,200	22,400	2,137,200
Christmas, g.s., Utah	.....	.....	.....	.....	.....	.....	1,500	3,000	.....	4,500
Church, g., Cal.	.....	.....	.....	.....	.....	3,000	.....	.....	.....	3,000
Cinnabar King, g., Cal.	.....	.....	.....	.....	.....	1,000	.....	.....	.....	1,000
Clarissa, g.s., Utah	.....	.....	.....	.....	.....	.....	5,000	5,000	.....	10,000
Cleveland, g., Utah	.....	.....	.....	.....	.....	2,000	1,000	.....	.....	3,000
Clyde Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	5,000	5,000
Columbia, g.s., Utah	.....	.....	.....	.....	.....	750	.....	.....	.....	750
Columbus Con., g.s., Cal.	.....	.....	.....	.....	.....	.....	.....	2,000	.....	2,000
Comstock, g. s. l., Utah	.....	.....	.....	.....	.....	.....	.....	.....	20,000	20,000
Confidence, s., Nev	.....	6,240	14,976	7,488	14,976	13,728	8,736	9,984	99,984	568,830
Conglomerate, g.s., Utah	.....	.....	.....	.....	.....	.....	.....	6,250	.....	6,250
Con. Cal. & Va., s., Nev	6 220	108,000	$54,000	118,800	108,000	108,000	108.000	97,200	.....	883,200
Con. Imperial, s., Nev	.....	.....	5,000	500	10,000	10,000	10,000	20,000	10,000	2,240,000
Con. New York, s., Nev	25,000	5,000	10,000	5,000	60,000	30,000	3,000	.....	.....	136,500
Con. St. Gothard, g., Cal.	.....	.....	.....	.....	.....	35,000	15,000	.....	10,000	60,000
Constellation, g., Utah	.....	.....	.....	.....	.....	.....	.....	2,250	2,250	63,000
Contra Costa Coal, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	30,000	30,000
Contra Costa Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	5,000	5,000
Corona Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	6,000	6,000
Crown Point, s., Nev.	80,000	65,000	25,000	70,000	.....	25,000	20,000	15,000	15,000	3,(20,000
Crusader Con., g.s.l., Utah	.....	.....	.....	.....	.....	.....	.....	5,000	.....	5,000
Dalton, g.s.l., Utah	3,750	5,000	5,000	5,000	2,500	7,500	5,000	.....	5,000	63,750
Daylight, g., Utah	.....	.....	.....	.....	.....	.....	.....	.....	2,000	2,000
Del Monte Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	20,000	20,000
Devil's Den Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	2,000	2,000
Dewey Gravel, g.s.l, Cal.	.....	.....	.....	.....	.....	.....	.....	10,000	.....	10,000
Dexter, g.s., Nev.	.....	.....	.....	.....	.....	30,000	.....	.....	.....	38,000
Diamond Con. g.s.l., Utah	.....	.....	.....	.....	.....	.....	8,000	.....	8,000	16,000
Dreisam, g., Cal.	.....	.....	.....	.....	.....	.....	51,000	15,000	.....	66,000
Dublin, g., Cal.	.....	.....	.....	.....	.....	.....	.....	.....	10,000	10,000
Dutch, g., Cal.	.....	.....	.....	.....	.....	.....	22,500	52,500	.....	75,000
Eagle, g., Oregon	.....	.....	.....	.....	.....	3,000	.....	.....	.....	3,000
East Valeo, g., Utah	.....	.....	.....	.....	.....	.....	.....	.....	5,000	5,000
Ella Eldon, g., S. Dak	.....	.....	.....	.....	.....	.....	.....	.....	500	500
El Rey, g., Utah	.....	.....	.....	.....	.....	.....	.....	8,000	.....	8,000
Ely, g., Utah	.....	.....	.....	.....	.....	.....	2,000	3,000	.....	5,(00
Emerald, g.s., Utah	.....	.....	.....	.....	.....	3,000	.....	.....	1,500	4,500
Empire Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	14,000	14,000
Eureka Con., s., Nev.	.....	.....	12,500	.....	.....	10,000	5,000	.....	.....	519,000
Eureka Con. Drift, g., Cal.	.....	.....	.....	.....	75,000	5,000	15,000	17,500	10,000	223,000
Eureka-Swansea Ext.,g.s.,Utah	.....	.....	.....	.....	.....	.....	.....	5,000	.....	5,000
Eutonia, s.l.g., Utah	.....	.....	.....	.....	.....	.....	.....	9,000	2,000	11,000
Excelsior Drift, g.s., Cal.	.....	.....	.....	.....	.....	667	5,000	2,000	.....	7,677
Exchange, g.s., Utah	.....	.....	.....	.....	.....	.....	.....	1,000	1,500	2,500
Exchequer, s., Nev.	15,000	10,000	5,000	5,000	5,000	.....	.....	3,000	.....	738,000
Fall Creek, g., Cal.	.....	.....	.....	.....	.....	.....	.....	.....	10,000	10,000
Fall River, g.s., Cal.	.....	.....	.....	.....	.....	.....	2,500	.....	.....	2,500
Father de Smet, g.s., S. Dak	.....	.....	.....	.....	.....	.....	.....	25,000	.....	225,000
Fish Springs, g., Utah	.....	.....	.....	.....	.....	.....	.....	1,500	.....	1,500
Florence, g.s., Utah	.....	.....	.....	.....	.....	.....	1,000	.....	.....	1,000
Forlorn Hope, g., Cal.	.....	.....	.....	.....	.....	20,000	.....	.....	.....	20,000
Four Aces, g.s., Utah	.....	.....	.....	.....	2,500	2,500	2,500	17,500	5,000	27,500
Free Coinage, g., Utah	.....	.....	.....	.....	.....	.....	.....	.....	5,000	5,000
Fremont, g.s., Utah	.....	.....	.....	.....	.....	.....	.....	2,500	.....	2,500
Frisco, g.s., Utah	.....	.....	.....	.....	.....	.....	2,000	2,000	.....	32,000
Fullerton & Sunset Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	3,000	3,000
Galata, g., Cal.	.....	.....	.....	.....	.....	10,000	.....	.....	.....	10,000
Galena, g., Utah	.....	.....	.....	.....	.....	10,000	.....	.....	5,000	15,000
Galena Treasure, g.s., S. Dak.	.....	.....	.....	.....	.....	.....	200	200	.....	400
Garden City, g.s., S. Dak.	.....	.....	.....	.....	.....	.....	.....	563	.....	7,105
Garibaldi, g.s., Cal.	.....	.....	.....	.....	.....	.....	4,000	4,000	.....	8,000
Genevieve, g.s., Utah	.....	.....	.....	.....	.....	.....	5,000	.....	.....	5,000
Gerrymander, g.s., Cal.	.....	.....	.....	.....	.....	.....	10,000	5,000	.....	15,000
Geyser, s.l., Colo	.....	.....	.....	.....	.....	50,000	200,000	.....	.....	1,275,000
Geyser-Marion, g.s., Utah	.....	.....	.....	.....	.....	.....	.....	9,000	.....	9,000
Giant Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	24,107	24,107
Gibraltar Con., g., Cal.	.....	.....	.....	.....	.....	.....	.....	.....	5,000	5,000
Golconda, g.s., Nev.	.....	.....	.....	.....	.....	.....	.....	.....	750	750
Gold Coin (Gilpin Co.), Colo.	.....	.....	.....	.....	.....	.....	10,000	.....	.....	10,000
Golden Channel, g., Cal.	.....	.....	.....	.....	.....	.....	3,000	2,500	.....	5,500
Golden Eagle, g.s., Nev.	.....	.....	.....	.....	.....	.....	4,000	.....	.....	4,000
Golden King, g., Cal.	.....	.....	.....	.....	.....	3,500	.....	.....	.....	3,500
Golden Star, g.s., Cal.	.....	.....	.....	.....	.....	.....	2,000	1,500	2,500	6,000
Gold Hill, g.s., Cal.	.....	.....	.....	.....	.....	.....	.....	25,000	25,000	50,000
Gold Hill, g.s., Utah	.....	.....	.....	.....	.....	.....	.....	500	500	1,500
Gold Leaf, g.s., Wash	.....	.....	.....	.....	.....	.....	100	.....	.....	100
Gold & Silver Carb., g.s., Uta.h	.....	.....	.....	.....	.....	.....	2,500	.....	.....	2,500
Goleta, Con.,g. Cl.	.....	.....	.....	.....	.....	.....	.....	63.000	30,000	93.0000
Gonyon, .gs., Utah	.....	.....	.....	.....	.....	.....	.....	2,500	3,750	6,250
Good Hope, g., Utah	.....	.....	.....	.....	.....	.....	.....	.....	2,000	2,000

ASSESSMENTS LEVIED BY MINING COMPANIES.—*Continued.*

Name of Company.	1893.	1894.	1895.	1896.	1897.	1898.	1899	1900.	1901.	Total Levied.
Good Title, g., Cal.						$20,000				$20,000
Gould Central Oil, Cal.									$5,000	5,000
Gould Oil, Cal.									25,000	25,000
Gould & Curry, s., Nev.	$80,200	$32,400	$48,600	$48,600	$59,400	37,800	$49,400	$54,800	43,200	4,786,450
Grand Prize Oil, Cal.									20,000	20,000
Granite Hill, g.s., Cal.							3,000			3,000
Grape Vine Canyon, g.s., Cal.							10,000	14,000	10,000	24,000
Great Bonanza, g.s., Utah.								5,000		5,000
Great Eastern, g.s., Utah.						1,500	1,500	1,500		4,500
Great Western, q., Cal.						5,000	20,000			75,520
Grizzly, g.s., Cal.						1,500		5,000		6,500
Hale & Norcross, s., Nev.							39,200	22,400	11,200	5,751,080
Hanford-Fresno Oil, Cal.									24,140	24,140
Hanford-Sanger Oil, Cal.									6,000	6,000
Head Center Con., g.s.c., Ariz.							25,125			25,125
Hercules, g.s., Utah.								20,000		20,000
Hester A., g.s., S. Dak.								500		3,000
Highland, g.s., Utah.								8,00	0	8,000
Highland(Leadville), g.s.,Colo.								125,000		125,000
Hilda Gravel, g.s., Cal.						2,000		2,000		4,000
Hillside, g.s., Utah.							1,500			1,500
Himalaya, g.s., Utah.							5,000			5,000
Home, g.s , Cal.						3,000		10,000		13,000
Homestake, g.s., Utah.						4,000	4,000			12,000
Horn Silver Tunnel, g.s., Utah.							500	500		1,000
Horsefly, g., Cal.						8,000			10,000	18,000
Horseshoe Bar Con., g.s., Cal.						6,000	3,000	1,200	600	87,600
Humboldt, g.s., Cal.							2,000			2,000
Imperial Oil, Cal.									2,000	2,000
Imyo Marble, Cal.									5,000	17,000
Independence, g.s., Utah.							6,000	9,000		15,000
Independent, g., Cal.									10,000	10,000
Ingot, g.s.l., Utah.									10,000	10,000
International, g.s., Utah.							1,500			1,500
Jefferson, g.c., Utah.								1,500	1,750	3,250
Jennie Lind, g.s., Cal.							1,000	2,000	8,000	11,000
Joe Bowers, g.s., Utah.								14,000	21,000	35,000
Joe Bowers Ext., g.s., Utah.								15,000		40,500
Julia Con., s., Nev.	5,000		5,500	5,500	5,500		3,300	3,300		1,501,800
Jumbo, g.s., Utah.						500				500
Junction, g.s., Cal.						10,500	6,000			16,500
Jupiter Gravel, g., Cal.					40,000	40,000				80,000
Justice, s., Nev.						10,500	21,000	15,750	21,000	3,704,500
Karan, g., Cal.						2,500				2,500
Karl Brown Oil, Cal.									15,000	15,000
Kate Hayes, g.s., Cal.						10,000	10,000			70,000
Kentuck, g., Utah.						30,000				30,000
Kentuck Con., s., Nev.	10,500	26,250	10,500	5,250	10,500	5,250		3,150		128,450
Kern River Oil, Cal.									40,000	40,000
Kern Sunset Oil, Cal.									2,000	2,000
Kings County Oil, Cal.									6,000	6,000
Lady Washington, s., Nev.				5,400			5,400			168,300
La Grange, g.s., Cal.							15,000			15,000
Laird, g., Cal.						10,000				10,000
Larkin, g.s., Cal.						2,000	2,000	4,000	10,000	28,000
La Suerte, g.s., Cal.						7,500	7,500	7,500	5,000	27,500
Leon, g., Cal.						1,500				1,500
Linda Vista Oil, Cal.									11,460	11,460
Lion Con., g.s., Utah.							500	500		1,000
Little Bell, g., Utah.									37,500	37,500
Little Chief, g.s., Utah.							8,000	12,000	16,000	36,000
Little Pittsburg, g.s., Utah.			4,000	6,000	4,000	4,000	5,000			23,000
Live Oak Con., g.s., Cal.						20,000	10,000	10,000		40,000
Live Yankee, g.s., Cal.						5,000	2,000			7,050
Lombard, g.c., Utah.									1,250	1,250
Louis, S., g., Utah.									10,000	10,000
Lower Mammoth, g.s., Utah.						12,500	15,000	15,000		42,500
Lucky Bill, g.s., Utah.				7,200	6,600	1,800	2,500	2,400	12,000	73,000
Lulah Con., g.s., Utah.							1,500			1,500
Mammoth Garfield, g.s., Cal.								17,500		17,500
Maple Creek, g., Cal.									10,000	10,000
Maple, g.s., Utah.									3,000	3,000
Marguerite, g.s., Cal.					20,000	15,000	15,000			85,000
Marina Marsicano, g.s., Cal.					16,360	19,000	19,000	7,000	1,000	62,360
Mariposa Com'l&M'g.g.s.,Cal.								50,000	50,000	210,000
Martha Washington, g.s.,Utah.						3,000	6,000	6,000	9,000	24,000
Martin White, s., Nev.	25,000	25,000					120,000			1,200,000
Maxfield, g.s., Utah.						6,000	9,000	9,000		24,000
Mayday, g.s., Cal.						5,000	10,000	5,000	2,500	22,500
Mayday, g.s., Utah.						2,000	2,000			4,000
Mayflower Gravel, g.s., Cal.						6,000		7,500	6,000	19,500
Mayflower, g.s., Utah.								2,000	5,000	7,000
Mazeppa, g.s., Cal.								5,000		5,000
McKittrick, Con., Oil, Cal.								18,00	18,000	30,500

ASSESSMENTS LEVIED BY MINING COMPANIES.—*Continued.*

Name of Company.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	Total Levied.
McKittrick Oil, Cal.									$15,000	$15,000
Melcher, g.s., Utah								$2,000	1,250	3,250
Merrimac, g., Cal.						$20,000				20,000
Meteor, g.s., Utah						3,734	$4,999	2,997	1,980	13,690
Mexican, s., Nev.	$76,500	$75,600	$75,600	$40,320	$20,000	40,320	25,200	45,360	50,400	2,409,920
Midland, g s., Utah								3,000		3,000
Midnight Bowers, g.s., Utah							1,000	1,000		2,000
Minnehaha Oil, Cal.									10,000	10,000
Mohican g., Cal.									10,000	10,000
Molly Bawn, g.s., Utah							1,000			1,000
Montecito, g., Cal.						10,000				10,000
Montreal, g.s., Utah			375		375		25,000			30,625
Mooney Con., g.s., Cal.								20,000		20,000
Morgan, g., Cal.						10,000				10,000
Mountaineer, g.s., Cal.						15,000		25,000		40,000
Mountain View, g., Cal.									15,000	15,000
Mt. Blanc Con., g., Cal.									1,250	1,250
Mt. Diablo Oil, Cal.									10,000	60,000
Nancy Hanks, g., Cal.						5,000				5,000
Nashville, g., Cal.						2,000				2,000
National Con., g.s., Cal.						15,000	45,000	15,000	10,000	78,685
Navajo, g.s., Utah									2,500	2,500
Nevada, s., Nev.								10,000		10,000
New Century Oil, Cal									15,000	15,000
New Erie, g.s., Utah							2,000	500	7,500	10,000
New Imperial, g.s., Utah							1,000			1,000
New Klondike, g.s., Utah							2,961	235		3,196
New La Plata, g.s., S. Dak.								300		1,700
New Southern Cross, g., Mont.									5,000	5,000
New State, g.c., Utah								1,500		4,500
Nineteen Oil, Cal.									6,000	6,000
North Bloomfield, g., Cal.						25,000				25,000
North Bonanza, s., Nev.								15,000		255,000
North Gould & Curry, s., Nev.	10,000	20,000		10,000		20,000				375,000
North Mercur, g., Utah						10,000				10,000
North Rapidan, s., Nev.								8,000		8,000
Northern Light, g.s., Utah						8,000		8,000	18,000	34,000
Northern Spy, g.s., Utah						10,000	10,000			20,000
Nugget Placer, g., Cal.									10,000	10,000
Occidental Con., s., Nev.	55,000	30,000	30,000	65,000	30,000	20,000	20,000	5,000	10,000	534,179
Okanogan, g., Wash.								10,566		10,566
Old Bonanza, g.s., Cal.							2,500			2,500
Old Colony & Eureka, g.s., Utah.								2,500		2,500
Old Home, g.s., Cal.						5,000	3,500	3,500	1,000	13,000
Old Susan, g.s., Utah								7,500	500	8,000
Omaha Con., g.s., Cal.						10,000	25,000	100,000		135,000
Omaha, g.s., Utah								6,000		6,000
Ophir, s., Nev.	100,000	100,000	100,000	25,200	25,200	43,200	50,400	60,480	45,360	4,758,808
Opohonga, g.s., Utah						1,500	1,000			2,500
Orient, g.s., Cal.							50,000	75,000	35,000	160,000
Orient, g., Utah									2,500	2,500
Orleans, g.s., Cal.						15,000	12,000		5,000	32,000
Oro Quartz, g.s., Cal							4,500			4,500
Osceola Con., g.s., Cal.						1,000	1,000	2,000	2,000	15,810
Overman, s., Nev.	60,000	34,560	23,040	34,560	17,280	17,280	11,520	17,268	23,040	4,181,430
Pacific, g.s., Utah							500	750		1,250
Park City & Mid. Sun, Utah								10,000		10,000
Peabody, g.s., Cal.								10,000		10,000
Petroleum Center Oil, Cal.									61,500	82,000
Phœnix, g.s., Utah					1,000			1,000		2,000
Picnic, g.s., Utah								1,000		1,000
Potosi, s., Nev.	84,000	112,000	56,000	28,000	50,400	50,400	39,200	39,200	28,000	2,263,600
Powning, g.s., Cal.							2,500			2,500
Prior Hill, g.s., S. Dak.								200		1,000
Prosperity Oil, Cal.									25,000	25,000
Providence, g., Cal.									20,000	20,000
Provident Oil, Cal.									7,500	7,500
Queen Esther Oil, Cal.									5,000	5,000
Quincy, g., Cal.							10,000	20,000		30,000
Raven Oil, Cal.									10,500	10,500
Raymond, g., Utah.									12,500	12,500
Red Bank Oil, Cal.									6,000	6,000
Red Cap, g., Cal.						90,000				90,000
Reddick, g.s., Cal.						5,000	5,000			10,000
Red Jacket, s., Nev.							2,000			2,000
R. G. W., g.s., Utah.							2,000	1,000	2,500	5,500
Rescue Gold, Nev.					3,000	2,000	500			5,500
Revenue, g.s., Utah							4,500			4,500
Reward, g.s., Cal.					7,040	3,840	3,200	9,920	14,500	91,500
Rich Bar Gravel, g.s., Cal.								6,000		6,000
Richmond, g., Cal.						10,000				10,000
Ridge & Valley, g.s., Utah.								5,000	10,000	15,000
Roberts Oil, Cal.									3,000	3,000
Rockland, g., Cal.						3,000				3,000

ASSESSMENTS LEVIED BY MINING COMPANIES.—*Concluded.*

Name of Company.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	Total Levied.
Rose Creek, g.s., Cal.	.....	.....	.....	.....	.....	$5,000	$5,000	.....	.....	$10,000
Ruby Hill, g.s., Utah.	.....	.....	.....	.....	.....	.....	.....	$600	$1,000	1,600
Sacramento, g.s., Utah.	.....	.....	.....	.....	.....	.....	600	.....	2,500	3,100
Sailor Con., g.s., Cal.	.....	.....	.....	.....	.....	.....	11,000	6,000	3,000	20,000
Salmon River, s., Nev.	.....	.....	.....	.....	.....	.....	1,425	.....	.....	11,970
Salt Lake & Nev., g.s., Utah.	.....	.....	.....	.....	.....	1,000	.....	.....	2,500	3,500
Santa Rosalia, q., Mex.	.....	.....	.....	.....	.....	.....	.....	5,000	.....	5,000
Savage, s., Nev.	112,000	100,805	$67,200	$67,200	$67,200	44,800	22,400	33,600	22,400	7,366,000
Scorpion, s., Nev.	.....	5,000	.....	.....	5,000	.....	.....	3,000	.....	448,000
Sea Breeze Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	20,000	20,000
Sea Swan, g., Utah.	.....	.....	.....	.....	.....	.....	.....	.....	2,500	2,500
Seg. Belch. & Mides, s., Nev.	35,000	20,000	30,000	10,000	10,000	8,000	10,000	6,000	6,000	390,000
Sharp, g., Utah.	.....	.....	.....	.....	.....	.....	.....	.....	5,000	5,000
Shasta Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	20,000	20,000
Sheba, g.s., Cal.	.....	.....	.....	.....	.....	.....	.....	10,000	.....	10,000
Sheep Rock, g.s., Utah.	.....	.....	.....	.....	5,250	.....	.....	52,500	.....	57,750
Shoebridge Bonanza, g.s., Utah.	.....	.....	.....	.....	.....	.....	.....	3,200	4,000	13,600
Shower Con., g.s., Utah.	.....	.....	.....	.....	.....	.....	8,000	2,000	24,000	34,000
Sierra Nevada, s., Nev.	45,000	50,000	50,000	50,000	40,000	20,000	50,000	45,000	50,000	6,851,910
Silver Bell, s., Mont.	.....	.....	.....	.....	.....	5,000	.....	.....	.....	5,000
Silver Bow, g.s., Utah.	.....	.....	.....	.....	.....	.....	.....	5,000	7,500	12,500
Silver Cloud, g.s., Utah.	.....	.....	.....	.....	.....	.....	5,000	.....	2,500	7,500
Silver Hill, s., Nev.	5,400	5,400	.....	.....	5,400	5,400	.....	.....	.....	2,220,200
Silver King, g.s., Ariz.	.....	100,000	.....	75,000	50,000	50,000	50,000	25,000	25,000	515,000
Silver Park, g.s., Utah.	.....	.....	.....	.....	.....	.....	.....	9,000	.....	9,000
Silver Queen, g.s., Utah.	.....	.....	.....	.....	.....	.....	.....	1,000	.....	1,000
Silver State, g.s., Utah.	.....	.....	.....	.....	1,000	.....	.....	500	.....	1,500
Siskiyou Con., g.s., Cal.	9,000	14,000	4,000	2,000	.....	3,000	3,000	6,000	.....	55,000
Skagit Cumb. Coal, Wash.	.....	.....	.....	.....	.....	.....	.....	7,500	22,500	29,500
Skylark, c., Utah.	.....	.....	.....	.....	.....	.....	.....	.....	5,000	5,000
Snow Flake, g.s., Utah.	.....	.....	.....	.....	.....	2,000	5,000	2,000	7,000	28,500
Sonora Quartz, g.s., Mex.	.....	.....	.....	.....	.....	.....	.....	5,000	.....	5,000
South Bingham, g.s., Utah.	.....	.....	.....	.....	.....	.....	2,500	2,500	.....	5,000
South Eureka, g.s., Cal.	.....	.....	.....	.....	.....	.....	6,000	.....	.....	6,000
South Fork Con., g.s., Utah.	.....	.....	.....	.....	.....	5,000	.....	.....	.....	5,000
South Paloma, g.s., Cal.	.....	.....	.....	.....	.....	.....	.....	1,200	.....	1,200
South Sliger, g., Cal.	.....	.....	.....	.....	.....	.....	.....	.....	10,000	10,000
Spanish Bar, g.s., Cal.	.....	.....	.....	.....	.....	2,000	5,000	11,000	5,000	23,000
Star, g.s., Utah.	.....	.....	.....	.....	.....	5,000	30,000	25,000	.....	66,000
Sterling, g., Cal.	.....	.....	.....	.....	.....	15,000	.....	.....	.....	15,000
Success, g.s., Utah	.....	.....	.....	.....	.....	.....	9,750	3,000	.....	12,750
Sunbeam Con., g.s., Utah.	.....	.....	.....	.....	11,250	5,000	50,000	55,000	.....	131,363
Sweet Vengeance, g.s., Cal.	.....	.....	.....	.....	.....	.....	.....	10,000	.....	130,000
Tanama, g.s., Cal.	.....	.....	.....	.....	.....	.....	10,000	.....	30,000	40,000
Tesora, g.s., Utah.	.....	.....	.....	.....	.....	.....	.....	2,750	80,000	102,000
Tetro, g.s., Utah.	.....	.....	.....	.....	.....	18,000	15,000	15,000	27,000	78,500
Texas, g.s., Cal.	.....	.....	.....	.....	.....	.....	15,000	30,000	10,000	55,000
Thorpe, g.s., Cal.	.....	.....	.....	.....	.....	5,000	5,000	.....	.....	10,000
Tintic, g.s, Utah.	.....	.....	.....	.....	.....	.....	4,375	.....	.....	4,375
Tomboy, g., Utah.	.....	.....	.....	.....	.....	.....	.....	.....	.....	5,000
Tracy, g.s., Cal.	.....	.....	.....	.....	.....	.....	5,000	.....	.....	5,000
Troy, g.s., Alaska.	.....	.....	.....	.....	2,000	6,250	6,250	.....	.....	16,750
Tuscarora Chief, g.s., Utah.	.....	.....	.....	.....	.....	.....	2,000	.....	.....	2,000
Ukiah Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	10,000	10,000
Union Con., s., Nev.	45,000	35,000	20,000	40,000	20,000	30,000	18,000	30,000	25,000	2,715,000
United Sunbeam, g., Utah.	.....	.....	.....	.....	.....	.....	.....	.....	30,000	30,000
U. S. Grant, g.s., S. Dak.	.....	.....	.....	.....	.....	.....	.....	1,000	.....	4,500
Utah Con., s., Nev.	25,000	5,000	5,000	10,000	30,000	20,000	15,000	15,000	20,000	520,000
Valeo, g.s., Utah.	.....	.....	.....	.....	.....	.....	10,000	10,000	.....	20,000
Vallejo, q., Cal.	.....	.....	.....	.....	.....	2,000	2,000	.....	.....	4,000
Valley View Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	17,500	17,500
Vernon Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	25,000	25,000
Victor, g.s., Utah.	.....	.....	.....	375	.....	.....	.....	15,000	5,000	26,000
Victoria, g.s., Utah.	.....	.....	.....	.....	.....	.....	.....	4,000	.....	4,000
Victory, g.s., S. Dak.	.....	.....	.....	.....	.....	.....	.....	200	.....	2,825
Wasatch, Utah.	.....	.....	.....	.....	.....	.....	.....	.....	6,000	6,000
Washington Con., g.s., Wash.	.....	.....	.....	.....	.....	.....	.....	200	.....	2,000
Washington Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	7,000	7,000
Watt Blue Gravel, g.s., Cal.	.....	.....	.....	.....	.....	.....	3,000	.....	.....	58,000
Wellington Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	70,000	70,000
West Argent, Utah.	.....	.....	.....	.....	.....	.....	.....	.....	10,000	10,000
West Lake Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	10,000	10,000
West Morn'g Glory, g.s., Utah.	.....	.....	.....	.....	.....	.....	.....	1,250	1,250	7,250
West M't'n Placer, g.s., Utah.	.....	.....	.....	.....	.....	.....	.....	8,000	3,750	11,750
Willietta, g., Cal.	.....	.....	.....	.....	.....	.....	.....	.....	10,000	10,000
Wisconsin Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	25,000	25,000
Yankee Con., g.s., Utah.	.....	.....	.....	.....	.....	.....	2,500	5,000	10,000	17,500
Yankee Girl, g.s., Utah.	.....	.....	.....	.....	.....	.....	5,000	.....	.....	5,000
Yellow Jacket, s., Nev.	90,000	90,000	90,000	90,000	.....	24,000	36,000	42,000	36,000	5,904,000
Young America, g.s., Utah.	.....	.....	.....	.....	.....	.....	.....	8,000	.....	8,000
Yuba Con., g., Cal.	.....	.....	.....	.....	.....	2,500	.....	.....	45,000	47,500
Zacca Lake Oil, Cal.	.....	.....	.....	.....	.....	.....	.....	.....	1,875	1,875
Zuba, g., Cal.	.....	.....	.....	.....	.....	5,000	.....	.....	.....	5,000

c., copper; g., gold; i., iron; l., lead; q., quicksilver; s., silver; z., zinc.

AUSTRALASIA.

THE most important articles of mineral production in the seven colonies of Australasia are gold, silver, lead, copper, tin, iron and coal. These industries are referred to specifically under the respective captions elsewhere in this volume. The statistics of production, imports and exports as reported in the official statistics are summarized in the following tables:

MINERAL PRODUCTION OF NEW SOUTH WALES. (*a*) (*c*) (IN METRIC TONS AND DOLLARS; £1—$5.)

Year.	Alunite.		Antimony and Ore.		Bismuth.		Chrome Ore		Clay. (Fire.)		Coal.		Cobalt Ore.		Coke.	
1896....	1,393	$20,580	135	$9,170	41	$2,450	3,913	$56,400	35	$345	3,972,068	$5,627,405	.....	.....	26,773	$109,255
1897....	736	10,960	172	18,060	3	4,000	3,433	51,345	.....	.....	4,453,729	6,150,205	.....	.....	65,229	226,960
1898....	2,988	44,115	84	4,580	30	23,075	2,145	31,505	15	160	4,781,551	6,359,163	119	2,800	83,538	324,674
1899....	935	13,815	332	13,470	16	16,775	5,327	87,080	27	330	4,670,580	6,628,995	193	4,495	98,074	395,650
1900....	1,946	28,725	252	12,145	11	28,200	3,338	59,135	29	545	5,595,879	8,344,555	145	7,950	128,238	548,100

Year.	Copper Ingot.		Copper Ore and Regulus.		Gold—Kg.		Iron. (*b*)		Iron Oxide		Lead, Argentiferous.			
											Metal	Ore.	Value.	
1896....	4,524	$1,001,180	15	$375	9,231·2	$5,366,800	4,798	$166,415	381	$4,005	19,886	271,640	$8,794,665	
1897....	6,864	1,499,145	169	4,255	9,088·9	5,442,065	3,291	109,810	234	2,680	18,395	275,249	8,407,640	
1898....	5,744	1,400,240	181	4,195	10,590·4	6,223,649	5,233	211,250	398	4,160	10,270	394,676	8,223,895	
1899....	4,715	1,650,600	1,358	348,470	15,433·3	8,759,075	6,604	277,500	402	4,230	20,614	431,126	9,968,790	
1900....	5,712	1,975,515	1,494	164,665	10,801·6	5,972,605	7,101	305,420	318	3,430	19,400	426,480	12,569,370	

Year.	Lead, Pig.		Manganese Ore.		Opal—Kg.		Platinum. Kg.		Shale, Oil.		Silver—Kg.		Stone.	
													Limestone Flux	
1896....	24	$1,295	..	.....	630·4	$125,000	75·8	$17,395	32,348	$171,010	6,807	$132,590	90,346	$271,305
1897....	32	1,990	..	.....	2400·4	475,000	61·2	14,745	34,635	209,060	4,666	83,555	68,671	208,990
1898....	1,745	96,410	1	$25	.....	400,000	38·9	10,310	30,164	159,170	16,580	296,890	9,401	28,915
1899....	(*d*) 4,896	498,945	*Nil*	.....	.....	675,000	19·8	5,350	37,307	204,115	21,525	384,565	1,016	3,750
1900....	(*d*) 6,807	695,730	18	2 0	.....	400,000	15.6	5,035	23,229	103,260	24,080	451,215	17,273	19,610

Year.	Tin, Ingot.		Tin Ore.		Zinc Ore.		Sundry Minerals
1896....	1,737	$496,060	98	$14,525	.....	.....	$4,620
1897....	1,159	350,640	14	2,800	29,303	$118,440	37,160
1898....	908	302,825	1	175	39,564	144,705	10,105
1899....	895	490,690	5	1,450	50,677	246,035	24,850
1900....	915	600,160	15	4,500	20,594	220,930	555,245

(*a*) From the Annual Report of the Department of Mines and Agriculture, New South Wales. (*b*) Manufactured from old iron. (*c*) In addition to the above there is a small output of diamonds, which amounted to 56,352 carats ($156,965) for the ten years preceding 1898. (*d*) Includes carbonate and chloride.

MINERAL IMPORTS OF NEW SOUTH WALES. (*a*) (IN METRIC TONS AND DOLLARS; £1 = $5.)

Year.	Brass. (Yellow Metal.)	Cement—*Barrels.*		Chrome Ore.		Coal.		Coke.		Copper. In Matte and Regulus.	
1896....	$92,895	126,242	$239,025	5,537	$109,920	807	$4,870	43,824	$675,535	93	$19,380
1897....	69,290	184,881	408,210	2,731	49,240	1,755	6,065	33,970	511,980	42	8,680
1898....	102,250	183,851	418,580	1,780	82,770	666	2,985	4,064	61,735	.....	.....
1899....	142,945	247,393	622,245	4,009	63,280	2,453	6,520	433	8,020	91	16,755
1900....	194,500	177,076	455,455	279	4,125	2,743	20,205	516	10,750	22	1,275

Year.	Copper—*Continued.* Ingot.		Ore.		Rod, Sheet, and Wire.	Gold. Coin.	Bullion and Ores.	Iron and Steel. Pig.		Ore.		Manufactures. (*c*)	
1896....	5	$1,085	315	$12,875	$27,895	$2,407,100	$9,943,755	3,195	$124,255	108	$555	67,978	$3,626,075
1897....	6	1,585	1,401	92,440	96,445	5,749,095	10,328,540	16,256	269,470	1,293	8,095	71,469	3,904,105
1898....	3	1,000	1,013	40,245	61,635	18,323,980	9,779,270	12,081	189,885	2,688	8,525	65,140	3,621,285
1899....	43	11,560	9,209	346,500	135,370	3,510,800	12,908,555	9,153	168,395	4,205	14,615	89,257	5,224,515
1900....	35	12,400	7,076	366,470	239,605	7,212,885	12,729,040	13,280	333,130	6,350	20,545	86,888	6,208,885

Year.	Lead. Pig.		Pipe, Sheet and Old.		Nickel Ore.		Petroleum, Refined. *Liters.*		Potassium Salts. Nitrate.		Quicksilver. *Flasks.*	
1896....	7,440	$362,720	268	$19,720	3	$120	9,538,367	$438,375	162	$19,905	261	$9,250
1897....	5,281	289,590	308	20,235	208	5,000	11,027,291	492,275	176	18,455	470	12,255
1898....	2,379	135,330	49	3,685	788	7,575	13,728,963	563,690	181	17,170	469	17,005
1899....	1,963	125,580	75	6,145	(*b*)	.....	17,335,661	883,255	114	11,115	398	17,010
1900....	5,787	444,560	23	3,705	508	10,300	16,897,928	907,900	122	13,565	228	10,425

Year.	Salt. Rock.		Brine. *Bags.*		Silver. Coin.	Ingot—Kg.		In Matte—Kg.		Ore.		Slate. Roofing—*Number*	
1896....	7,275	$39,625	25,784	$207,560	$49,000	180	$3,900	3,958	$79,245	15,073	$672,770	2,219,681	$90,595
1897....	4,654	34,110	36,722	261,230	131,630	288	5,060	1,928	35,500	1,288	33,680	1,908,475	78,990
1898....	8,647	59,220	30,991	217,115	236,010	267	4,980	.....	.....	984	37,625	1,893,871	90,240
1899....	7,987	46,490	34,537	231,740	354,185	299	5,975	1,045	18,715	3,070	95,045	2,835,637	113,690
1900....	3,662	23,120	28,305	210,790	810,480	342	6,955	132	2,370	1,880	83,445	2,350,980	96,025

Year.	Slate—*Cont'd.* Slabs. *Number.*		Sodium Salts. Bicarbonate.		Carbonate. (Crude.)		Carbonate. (Crystals.)		Hydrate. (Caustic.)		Stone, Excepting Marble.
1896....	3,602	$11,675	611	$25,080	1,749	$60,300	745	$18,305	1,010	$48,465	$40,925
1897....	2,605	8,575	788	31,395	1,452	50,583	495	7,940	1,218	66,900	27,065
1898....	3,482	12,430	953	36,495	1,469	38,905	468	13,440	1,241	63,225	30,235
1899....	5,307	13,135	1,200	39,080	1,716	42,525	566	19,375	1,209	61,680	31,065
1900....	10,176	20,230	979	32,475	1,841	39,755	185	5,180	1,492	81,765	46,520

Year.	Sulphur.		Tin. Ingot.		Ore.		Plates.	Zinc. Slabs.		Sheet and Manufactures.	
1896....	1,330	$22,235	910	$265,505	1,073	$169,875	$353,345	1,416	$116,115	368	$35,500
1897....	2,287	33,955	693	205,135	662	104,510	200,350	1,341	122,815	561	58,010
1898....	1,845	26,960	478	161,245	554	92,665	373,060	1,220	122,325	377	43,905
1899....	1,575	23,575	681	396,095	868	262,455	258,035	724	90,720	225	35,005
1900....	2,208	56,510	299	195,205	741	254,710	643,940	1,084	122,325	514	73,000

(*a*) From the *New South Wales Statistical Register*. (*b*) Not stated in the reports. (*c*) In addition there were imports of manufactures for which no weights are stated; in 1897, $68,495; 1898, $136,640; 1899, $86,690 and in 1900, $96,205.

MINERAL EXPORTS OF NEW SOUTH WALES. (*a*) (*e*) (IN METRIC TONS AND DOLLARS; £1 = $5.)

Year.	Antimony. Ore.		Auriferous.		Metal.		Bismuth Ore.		Cement. *Barrels.*		Chrome Ore.	Coal.		Cobalt Ore.	
1896..	87	$2,810	25	$3,160	23	$3,200	45·0	$3,350	33,987	$74,650	9,465	$145,165	2,514,506	$4,501,330	284	$9,750
1897..	49	2,510	21	1,500	103	14,050	d3·3	4,150	15,272	39,185	5,959	101,320	2,739,769	4,760,270	73	2,500
1898..	57	2,150	13	795	13	1,570	31·5	23,775	16,801	45,420	6,924	122,775	2,836,465	4,813,340	184	4,450
1899..	314	11,820	18	1,650	1	20	15·8	16,775	12,297	36,090	9,795	167,930	2,843,310	5,028,970	347	11,095
1900..	258	12,680	(*c*)	.....	1	175	7·3	9,785	9,987	26,680	3,618	63,635	3,424,366	6,365,170	148	8,000

Year.	Coke.		Copper. Ingot.		Copper. In Matte.		Copper. Ore.		Copper. Rod, Sheet, Wire.	Gold. Ore.	Gold. Coin.
1896....	5,521	$22,615	4,026	$904,540	595	$117,595	15	$375	$8,000	$488,425	$18,014,980
1897....	32,321	135,225	4,126	964,880	2,778	549,440	169	4,255	5,770	282,040	21,738,235
1898....	31,284	125,330	5,285	1,235,715	460	114,765	181	4,195	12,950	227,410	32,545,300
1899....	43,706	181,980	5,532	1,936,700	1,163	397,660	482	17,710	21,245	13,970	17,446,430
1900....	75,598	302,755	6,771	2,341,985	626	129,195	867	35,470	13,885	19,705	26,949,110

Year.	Gold—*Continued.* Bullion—Kg.		Iron and Steel. Pig Iron.		Iron and Steel. Manufactures. (*b*)		Lead. Pig.		Lead. Pipe and Sheet.		Lead. Argentiferous.		Nickel Ore.	
1896....	2,576	$1,417,520	1,470	$26,350	17,289	$1,039,375	3,150	$167,425	750	$52,535	19,897	$3,974,335	(*c*)	.....
1897....	3,295	2,043,990	1,183	22,495	19,515	1,297,320	2,100	119,395	1,043	77,725	18,395	3,227,385	203	$4,900
1898....	3,326	2,022,925	1,294	31,060	15,454	1,021,015	3,367	191,210	707	57,945	10,271	1,605,690	785	9,800
1899....	7,209	4,614,655	639	12,785	16,550	1,176,695	4,865	333,225	1,339	125,160	20,582	2,023,640	71	840
1900....	3,930	2,302,390	835	22,125	18,269	1,415,415	7,362	573,415	1,420	136,525	18,277	1,794,320	(*c*)	.....

Year.	Salt. Rock.		Salt. Brine—*Bags.*		Silver. Coin.	Silver. In Matte—Kg.		Silver. Ore.		Sodium Salts. Bicarbonate.		Sodium Salts. Carbonate. (Crude.)	
1896....	457	$3,605	2,820	$32,440	$66,450	7,550	$152,960	284,524	$5,447,925	39	$1,790	207	$7,010
1897....	330	3,065	4,752	58,380	99,545	2,454	41,860	275,807	5,205,525	61	2,795	117	4,010
1898....	433	3,635	5,166	60,445	149 360	8,794	152,655	396,057	6,684,955	124	5,580	285	9,595
1899....	315	2,520	5,491	59,985	312,475	17,583	312,665	432,520	7,901,180	105	3,915	139	4,145
1900....	392	3,600	2,904	30,595	308,590	27,887	519,500	428,615	10,816,160	117	4,215	217	6,640

Year.	Sodium Salts—*Continued.* Hydrate. (Caustic.)		Sodium Salts—*Continued.* Nitrate.		Stone.	Sulphur.		Sulphuric Acid.		Tin. Ingot.		Tin. Ore.		Tin. Plate.
1896....	148	$7,545	17	$790	$7,015	139	$4,240	100	$5,535	2,646	$763,595	99	$14,525	$79,100
1897....	90	4,660	6	5,730	3,545	32	1,300	52	3,495	1,837	556,345	143	2,800	78,205
1898....	132	6,530	42	4,365	3,505	38	1,565	24	1,390	1,984	481,925	1	175	55,040
1899....	297	12,725	37	1,840	5,575	102	4,175	43	2,460	1,876	1,108,735	7	2,225	141,560
1900....	191	11,490	20	2,300	7,040	99	4,215	58	3,750	1.777	1,159,035	15	4,500	122,770

(*a*) From the *New South Wales Statistical Register*. (*b*) Values including those of manufactures for which no quantity is stated, as follows: In 1896, $17,970; 1897, $9,125; 1898, $14,445; 1899, $13,150 and in 1900, $9,810. (*c*) Not stated in the reports. (*d*) Probably bismuth metal. (*e*) There was also exported from N. S. W. in 1897, iron oxide: 246 metric tons, $2,830, and iron ore, 5 metric tons, $35.

MINERAL PRODUCTION OF NEW ZEALAND. (*a*) (*b*) (IN METRIC TONS AND DOLLARS; £1—$5.)

Year.	Antimony Ore.		Coal.		Coke.		Gold—Kg.		Manganese Ore.	
1896.....	21	$2,250	805,537	$2,143,240	107	$1,315	8,202	$5,207,140	66	$1,025
1897.....	10	785	854,164	2,259,575	14	.....	7,827	4,901,020	183	2,705
1898.....	*Nil.*	.....	921,546	2,378,355	9	.....	8,714	5,403,445	220	3,515
1899.....	*Nil.*	.....	990,838	2,438,085	18	45	12,117	7,565,865	137	2,035
1900.....	3	505	1,111,860	2,734,975	*Nil.*	.....	11,675	7,198,010	166	2,940

MINERAL PRODUCTION—*Continued.*

Year.	Mixed Ores. Unspecified.		Silver—Kg.	
1896.....	38	$6,675	2,933	$52,945
1897.....	1,586	29,460	5,716	104,360
1898.....	1,857	23,960	9,140	165,535
1899.....	1,330	32,945	10,866	204,190
1900.....	2,126	68,755	10,202	260,360

MINERAL IMPORTS. (*c*) (IN METRIC TONS; £1—$5.)

Year.	Coal.		Machinery.	Railway Materials.	Tools and Implements.
1896.....	103,364	$470,690	$1,417,200	$163,270	$350,690
1897.....	112,681	490,695	2,005,265	682,855	450,905
1898.....	117,274	526,115	2,349,315	499,985	555,755
1899.....	101,259	464,075	2,267,075	630,820	465,100
1900.....	126,059	602,030	2,936,890	1,007,960	645,385

(*a*) From *New Zealand Mines Statements*, by the Hon. A. J. Cadman, Minister of Mines, Wellington. (*b*) The exports are stated to be identical with the production, except in the case of coal, of which substance the exports were as follows: In 1896, 80,796 tons, value, $359,920; in 1897, 77,280 tons, value, $347,975; in 1898, 57,333 tons, value, $251,905; in 1899, 90,912 tons, value, $415,425; in 1900, 116,216 tons, value, $497,870. (*c*) From *British Statistical Abstracts.*

MINERAL PRODUCTION OF QUEENSLAND. (*a*) (IN METRIC TONS AND DOLLARS; £1 = $5.)

Year.	Antimony Ore.		Bismuth Ore.		Coal.		Copper Ore.		Gems.	Gold—Kg.		Lead.		Manganese Ore.	
1895.....	(*c*)	.....	60	$16,290	328,237	$662,650	441	$65,485	*b*$29,575	19,647	$11,054,435	369	$18,170	361	$5,515
1896.....	(*c*)	.....	(*c*)	.....	377,332	774,985	589	105,210	(*c*)	19,917	11,206,787	628	30,900	305	4,500
1897.....	(*c*)	.....	1	670	364,142	699,445	293	63,225	(*c*)	25,129	12,765,705	391	20,585	403	7,530
1898.....	(*c*)	.....	8	3,500	414,461	752,465	63	10,830	(*c*)	28,616	13,751,745	252	12,400	68	1,255
1899.....	41	$1,000	2	2,470	501,913	878,575	164	47,490	(*c*)	29,451	14,190,585	57	3,650	747	14,155
1900.....	(*c*)	.....	8	9,325	505,252	868,595	386	115,200	4,500	30,099	14,359,545	207	16,795	77	1,085

Year.	Opal.	Silver Ore.		Silver—Kg.		Stone. Building. (*b*)		Tin Ore.		Tungsten Ore	
1895.....	$163,750	7	$10,060	6,999	$150,210	52,206	$53,305	2,148	$340,665	25	$2,710
1896.....	116,500	(*c*)	.....	8,687	160,810	(*c*)	.....	1,579	245,090	3	300
1897.....	51,250	(*c*)	.....	7,280	125,590	(*c*)	.....	1,222	187,545	13	975
1898.....	33,225	(*c*)	.....	3,235	52,925	(*c*)	.....	1,041	182,510	79	12,700
1899.....	45,000	(*c*)	.....	4,521	78,355	164,939	112,330	1,322	396,510	253	50,300
1900.....	37,500	(*c*)	.....	3,514	63,560	152,484	107,585	1,133	370,205	193	38,025

MINERAL IMPORTS OF QUEENSLAND. (*d*) (IN METRIC TONS AND DOLLARS; £1 = $5.)

Year.	Cement and Plaster of Paris—*Barrels.*		Coal.		Coke.		Glass and Glassware.	Gold Bullion—Kg.	
1895.....	47,244	$116,620	18,023	$91,575	(*c*)	.....	$147,615	56·3	$33,375
1896.....	68,607	163,360	18,743	88,225	5	$20	176,330	189·2	108,405
1897.....	65,280	159,375	21,624	98,370	81	505	103,060	176·9	91,490
1898.....	56,441	143,425	23,281	99,125	199	1,290	217,015	198·0	115,625
1899.....	86,986	233,735	33,963	135,825	*Nil.*	.....	164,895	306·4	172,260
1900.....	70,217	183,595	31,592	150,315	57	250	295,470	81·0	49,645

Year.	Gold Specie.	Iron and Steel.		Petroleum—*Gallons.*		Silver Bullion. Kg.		Silver Specie.
		Rails, Track Material.	All other.					
1895.....	$3,001,000	$139,980	$1,468,785	1,688,975	$282,530	7·1	$210	$1,750
1896.....	400,000	138,230	1,519,595	1,271,910	265,645	5·0	120	13,380
1897.....	59,350	121,950	1,586,605	1,369,178	278,070	11·1	265	113,145
1898.....	1,330,500	440,520	1,761,220	1,928,311	329,955	26·8	375	54,840
1899.....	818,000	385,360	2,660,860	1,867,755	357,485	8·6	175	152,655
1900.....	1,660,225	1,219,815	2,453,350	1,584,217	347,410	3·8	95	141,385

MINERAL EXPORTS OF QUEENSLAND. (*a*) (IN METRIC TONS AND DOLLARS; £1 = $5.)

Year.	Antimony Ore.		Bismuth Ore.		Copper.								Gold—Kg.		Gold Ore.	
					Ore.		Ingot.		Matte.		Regulus.					
1895..	44	$1,985	44	$24,760	102	$10,840	315	$62,695	225	$31,200	211	$51,885	21,529	$11,360,545	199	$9,955
1896..	(*c*)	.....	0·7	750	209	21,590	377	71,045	142	12,400	237	56,970	19,496	10,571,285	68	5,390
1897..	25	2,500	39	20,150	241	15,425	196	34,515	150	21,925	143	35,075	25,293	12,843,510	220	19,225
1898..	9	900	6	1,710	875	28,845	(*c*)	.....	5	1,325	2	1,980	29,390	14,278,905	748	75,790
1899..	15	2,110	2	1,755	737	54,620	4	1,070	104	22,405	137	84,660	31,656	14,574,950	513	47,455
1900..	11	1,575	5	5,135	1,970	176,150	(*c*)	.....	57	14,245	77	32,000	29,307	14,000,365	762	97,110

Year.	Precious Stones	Pyrites.		Silver.						Tin Ore.		Tin.		Tungsten Ore.	
				Ore.		Silver-Lead Bullion.		Precipitate.		Doré Bullion.—Kg.					
1895....	$29,575	(*c*)	....	77	$10,060	561	$198,710	1	$6,785	489	$26,340	1,180	$224,175	459	$146,760	34	$2,965
1896....	11,730	5	$770	181	46,350	174	108,630	0·8	1,500	3,163	144,460	751	136,410	355	97,485	23	2,355
1897....	5,700	(*c*)	....	259	35,080	301	37,350	(*c*)	.....	1,823	210,565	636	115,750	161	675	(*c*)	.....
1898....	7,735	(*c*)	....	207	39,370	(*c*)	.....	(*c*)	.....	1,951	206,065	535	103,455	150	55,900	2	190
1899....	11,950	(*c*)	....	332	54,986	4	875	(*c*)	.....	1,930	178,945	709	221,615	358	198,180	371	131,090
1900....	660	(*c*)	...	61	9,260	15	3,050	(*c*)	.....	1,047	159,780	596	209,075	283	190,715	289	69,765

(*a*) From *Annual Reports of the Under Secretary of Mines*, Queensland, when not otherwise stated. (*b*) From *Mineral Statistics of the United Kingdom.* (*c*) Not reported. (*d*) From *Statistical Abstracts for the Several Colonial and other Possessions of the United Kingdom.*

MINERAL IMPORTS OF SOUTH AUSTRALIA. (*a*) (IN METRIC TONS AND DOLLARS; £1—$5.)

Year.	Coal.		Coke.		Gold and Silver Bullion and Specie.	Iron. Bar, Sheet, Hoop, and Rod.		Iron. Galvanized, Plain, and Corrugated.		Silver-Lead. Metal.		Silver-Lead. Ore.	
1895..	261,117	$975,450	91,292	$531,872	$978,140	5,158	$163,205	4,153	$296,970	25,079	$4,293,305	134,878	$1,989,950
1896..	343,583	995,480	66,554	315,600	1,782,730	7,656	263,610	7,110	527,475	25,836	4,379,644	284,297	4,143,515
1897..	378,495	1,012,140	75,205	402,690	78,340	6,505	229,970	6,438	454,750	17,466	2,989,810	301,990	5,221,195
1898..	420,001	1,121,795	82,796	428,705	47,685	10,076	287,500	6,627	501,245	3,455	621,985	415,861	6,355,645
1899..	444,539	1,223,595	54,166	313,145	963,920	6,023	216,605	6,363	523,475	208	59,750	480,104	8,331,495
1900..	508,769	1,520,605	72,247	458,675	424,120	5,726	270,705	7,555	732,150	(*c*)	.....	571,528	11,499,005

(*a*) From *British Statistical Abstracts*, except the figures for 1896, which are from the *Statistical Register of South Australia.*

MINERAL EXPORTS OF SOUTH AUSTRALIA. (*a*) (IN METRIC TONS AND DOLLARS; £1—$5.)

Year.	Coal.		Copper.		Copper Ore.		Gold Bullion—Kg.		Lead.		Lead. Argentiferous.	
1895.....	876	$1,725	5,251	$1,132,470	268	$10,085	1,153·5	$643,960	20,766	$961,220	25,134	$3,096,310
1896.....	37,428	110,480	*b*4,689	1,097,320	354	15,750	265·1	157,905	24,353	1,183,630	13,899	1,416,555
1897.....	39,480	121,210	4,784	1,192,835	554	23,200	550·5	345,670	21,383	1,099,020	16,474	2,548,515
1898.....	39,899	124,680	*b*4,857	1,227,020	545	19,960	528·2	373,450	22,250	1,296,650	27,106	2,944,685
1899.....	47,568	154,440	*b*5,597	2,084,250	3,356	150,100	501·5	315,955	35,639	2,302,630	21,298	2,889,385
1900.....	78,945	269,515	*b*4,892	1,861,250	2,406	112,630	533·5	340,980	41,900	3,371,880	12,678	1,870,605

Year.	Lead Ore. Argentiferous.		Manganese Ore.		Matte.		Mica.	Salt.		Slate, Roofing.
1895.....	44,699	$1,129,015	49	$730	(*c*)	.....	(*c*)	(*c*)	.....	(*c*)
1896.....	129,488	3,652,360	(*c*)	.....	3,385	465,910	$1,660	*d*19,322	$127,260	$4,925
1897.....	180,870	5,394,000	(*c*)	.....	2,324	342,235	5,690	*d*29,374	174,805	18,865
1898.....	139,567	4,779,410	5	50	867	126,300	500	31,471	192,725	3,510
1899.....	188,916	5,869,280	102	500	1,293	174,110	(*c*)	35,633	220,570	5,260
1900.....	163,015	5,254,205	(*c*)	.....	(*c*)	.....	(*c*)	33,976	186,295	(*c*)

Year.	Tin Ore.		Zinc.		Various Ores.	
1895.....	70	$9,075	26	$1,610	6	$360
1896.....	(*e*)	.....	36	2,020	2	90
1897.....	(*e*)	.....	11	590	52	2,095
1898.....	5	25	18	1,290	30,931	516,765
1899.....	1	75	27	2,215	844	38,010
1900.....	(*c*)	.....	(*c*)	.....	(*c*)	.....

(*a*) From the *Mineral Statistics of the United Kingdom*, except the figures for 1896, which are from the *Statistical Register of South Australia*, Part IV. and those for 1897, which are from *British Statistical Abstracts*. (*b*) Includes yellow metal. (*c*) Not reported. (*d*) Exported in 1896 also rock salt, 3 metric tons ($50). In 1897, 2 metric tons ($30). (*e*) No tin ore exported in 1896: but tin, block and sheet, 5 metric tons ($1,795). In 1897 2 metric tons ($825).

MINERAL PRODUCTION OF TASMANIA. (*a*) (IN METRIC TONS AND DOLLARS; £1—$5.)

Year.	Coal.		Copper Ore.		Gold—Kg.		Iron Ore.		Lead-Silver Ore.		Stone. Bluestone. Cubic Yards	Bluestone. Tons.	Bluestone. Total Value.	Stone. Limestone. Tons	Limestone. Total Value.
1895	33,703	$70,145	34	$2,600	1,709	$1,061,645	(*b*)	.....	18,194	$879,785	7,144	7,961	$13,540	1,419	$7,500
1896	44,286	86,770	52	6,450	1,947	1,187,870	208	$250	21,150	1,114,740	4,256	(*b*)	3,425	2,621	3,101
1897	43,210	84,640	118,261	1,618,250	2,399	1,446,205	999	370	17,806	986,125	(*b*)	(*b*)	.....	1,702	6,200
1898	49,902	97,271	(*d*)	.....	2,309	1,407,425	1296	1,910	196,707	3,281,066	(*b*)	(*b*)	.....	45,324	53,195
1899	43,803	85,040	*e*60,985	2,792,860	2,612	1,637,725	(*b*)	.....	118,721	1,397,395	(*b*)	(*b*)	.....	71,747	302,699
1900	51,549	212,360	*f*4,221	317,945	1,716	1,029,480	(*b*)	.....	26,564	1,396,860	(*b*)	(*b*)	.....	47,671	65,245

Year.	Stone.—*Continued.* Freestone, Flagstones and Building Stones. Cubic Feet.	Loads	Total Value.	Rubble or Metal. Cubic Feet.	Tons.	Total Value.	Tin Ore. Quantity. Alluvial.	Lode.	Total.	Value. Alluvial.	Lode.	Total.
1895.. ...	21,470	(*b*)	$6,170	1,140	6,200	$5,175	3,867	29	3,996	$726,230	$180	$766,410
1896.....	13,575	4,230	7,590	*c*4,556	(*b*)	1,635	3,867	(*b*)	3,867	804,395	(*b*)	804,395
1897.....	82,197	(*b*)	5,805	95,202	18,274	11,010	3,281	1	3,282	545,545	85	545,630
1898.....	19,560	(*b*)	4,025	525,258	70,701	89,235	2,882	(*b*)	2,882	578,810	(*b*)	578,810
1899.....	14,400	(*b*)	3,079	88,425	12,060	13,151	3,333	(*b*)	3,333	1,354,320	(*b*)	1,354,320
1900.....	51,509	(*b*)	56,010	13,562	4,291	19,915	2,693	(*b*)	2,693	884,010	(*b*)	884,010

(*a*) From *Statistics of the Colony of Tasmania*, Part V., Production. There was also mined in 1898, 6 tons of nickel ore, valued at $2,000. (*b*) Not reported. (*c*) Represents car-loads. (*d*) Included with silver-lead ore. (*e*) In addition there were produced 8,498 tons of copper bullion, valued at $3,349,800. (*f*) In addition there were produced 9,343 tons of copper blister, valued at $4,190,355.

MINERAL IMPORTS OF TASMANIA. (a) (IN METRIC TONS AND DOLLARS; £1=$5.)

Year.	Cement and Whiting.		Coal and Coke.		Copper and Lead.	Glass, Sheet, Crown, and Plate.	Glassware Including Earthenware.	Gold Specie.	Iron. Railway Material	Iron and Tin Plate.	Jewelry and Plate.	Silver Specie and Bullion.
1895....	1,605	$14,855	36,139	$56,615	$5,590	$8,125	$36,140	$485,000	$58,465	$115,120	$11,960	$15,065
1896....	897	8,775	28,145	11,838	5,105	10,525	69,010	(b)	148,960	179,335	22,250	11,100
1897....	1,607	16,895	41,436	105,475	4,950	15,795	84,845	250,000	89,190	254,500	44,740	3,135
1898....	2,465	31,985	47,371	115,271	10,740	18,072	78,020	10,045	239,617	280,862	50,175	58,580
1899....	1,708	21,342	75,708	212,665	17,700	17,085	109,225	96,000	218,504	353,454	54,704	48,115
1900....	3,088	43,785	87,376	252,140	23,000	27,965	189,740	130,000	348,180	513,095	68,530	78,955

(a) From *Statistics of the Colony of Tasmania.* (b) Not reported.

MINERAL EXPORTS OF TASMANIA. (a) (IN METRIC TONS AND DOLLARS; £1=$5.)

Year.	Bismuth Ore.		Coal and Coke.		Copper Ore.		Copper. Blister.		Glassware Including Earthenware.	Gold.				
										Ore.		Bullion—Kg.		Coin.
1895....	(b)	.....	101	$705	205	$48,385	(b)	.....	$40	395·0	$28,690	1,664	$1,062,650	$58,950
1896....	1·0	$400	380	680	86	8,295	(b)	.....	545	1,032·0	42,835	1,759	1,118,065	(b)
1897....	(b)	.....	2,371	3,095	53	4,560	4,585	$1,825,585	360	421·6	19,970	1,889	1,181,440	(b)
1898....	4	550	2,605	3,269	467	30,660	5,092	1,861,165	(b)	1,074·9	18,065	1,521	924,325	395,000
1899....	6	4,500	2,740	6,005	1,755	119,125	8,476	3,690,275	(b)	547·6	23,505	1,647	1,006,175	(b)
1900....	(b)	.....	2,732	5,150	4,289	317,945	9,343	4,190,355	(b)	80·5	1,600	1,739	1 022,720	(b)

Year.	Iron.				Iron Oxide.		Lead.		Silver.				Tin.	
	Old Metal.		Rails.						Ore.		Bullion.		Ore.	
1895....	96	$670	117	$1,395	66	$825	7·0	$380	20,575	$1,139,580	(b)	.....	18	$1,465
1896....	300	2,710	61	900	29	145	2·5	100	21,150	1,114,740	(b)	.....	2	10
1897....	198	1,450	57	50	(b)	.....	19·3	725	19,828	1,084,465	(b)	.....	5	2,960
1898....	117	1,295	(b)	.....	20	110	(b)	.....	14,168	888,090	(b)	.....	6	835
1899....	96	745	(b)	.....	6	30	5	290	13,618	812,090	1,453	$232,255	58	18,120
1900....	(b)	.....	(b)	.....	(b)	.....	5·5	415	12,387	860,830	2,337	399,570	13	3,195

Year.	Tin.—*Continued.*		Zinc.	
	Metal.			
1895....	2,771	$837,305	9	$500
1896....	2,743	795,180	10	880
1897....	2,462	749,970	42	1.890
1898....	2,006	705,810	6	265
1899....	2,278	1,391,615	8	660
1900....	2,062	1,349,165	27	1,585

(a) From *Statistics of the Colony of Tasmania.* Additional exports in 1897: Jewelry and plate, $6,105; silver coin, $12,875; unclassified ore, 30 metric tons, $1,450; mineral sand, ½ metric ton, $5; copper metal, 1½ tons, $40; iron ore, 904 tons, $4,015; manganese ore, 2 tons, $30; mineral oxide, 5 tons, $45; in 1898: Jewelry and plate, $3,395; iron ore, 1,735 tons, $8,540; in 1899: Asbestic, 208 tons, $1,815; tin plates, $2,150; iron ore, 3,685 tons, $17,350. (b) Not stated in the reports.

MINERAL PRODUCTION OF VICTORIA. (a) (IN METRIC TONS AND DOLLARS; £1=$5.)

Year.	Antimony Ore.		Coal.		Lignite.		Copper Ore		Gold—Kg. (b)		Lead Ore. Argentif.		Slate and Flagging.		Tin Ore.	
1895..	(d)	.....	197,334	$592,000	1,988	$5,239	7	$1,050	28,019	$14,801,720	20	$500	366	$450	76	$15,662
1896..	(d)	.....	230,187	565,060	5,908	10,705	(d)	.....	25,041	16,101,740	(d)	.....	386	485	47	8,995
1897..	5	$100	240,057	543,200	4,894	6,885	(d)	.....	25,280	16,255,320	(d)	.....	(d)	e125,000	48	8,250
1898..	118	2,550	246,845	515,495	2,915	3,835	(d)	.....	26,041	16,745,140	20	1,200	(d)	100,000	87	19,585
1899..	(d)	.....	266,578	567,610	(d)	.....	(d)	.....	26,578	17,090,000	(d)	.....	(d)	.....	158	56,000
1900..	(d)	.....	215,052	507,995	(d)	.....	(d)	.....	25,231	16,148,440	(d)	.....	(d)	175,000	71	25,105

MINERAL IMPORTS OF VICTORIA. (c)

Year.	Coal.		Iron and Steel.	
1895..	553,343	$1,005,235	42,788	$1,422,400
1896..	511,020	970,175	45,126	1,996,845
1897..	535,812	1,143,235	56,832	2,294,645
1898..	571,326	1,288,440	.....	2,674,705
1899..	532,076	1,380,685	.....	3,507,105
1900..	690,567	2,018,615	.....	3,762,985

MINERAL EXPORTS OF VICTORIA. (c)

Year.	Coal.		Coke and Charcoal.		Gold.		Silver. (Specie)
					Bullion.	Specie.	
1895..	161	$600	210	$2,060	$612,505	$18,141,180	$41,860
1896..	319	1,770	295	3,050	323,025	16,171,535	53,185
1897..	288	1,980	1,212	15,690	969,055	31,392,585	11,605
1898..	411	1,775	567	7,093	1,355,240	28,253,695	122,300
1899..	445	1,695	430	8,310	988,210	20,821,110	144,500
1900..	72,765	186,535	275	2,750	433,000	20,227,805	114,875

(a) From Annual Reports of the Secretary for Mines of the Colony; additional products in 1897: Bricks, estimated value, $11,250; pottery, estimated value, $8,900; in 1898: Brick, $12,500; pottery, $10,000; infusorial earth, 142 tons, $1,400; in 1899: Infusorial earth, $1,250; brick, $15,000; pottery, $12,500; building brick, $100,000. (b) The values are not separately stated in the report, and are estimated at $20 per oz.=$643·02 per kg. (c) From *British Statistical Abstracts.* (d) Not stated in the reports. (e) Represents estimated value of building stones basalt, sandstone, granite, slate, flagging, etc.).

MINERAL IMPORTS OF WESTERN AUSTRALIA. (*a*) (IN METRIC TONS AND DOLLARS; £1 = $5.)

Year.	Brassware.	Cement. *No. of Barrels.*		Clay. Bricks.	Clay. Earthen and Chinaware.	Clay. Tiles.	Coal.		Coke and Patent Fuel. *No. of Sacks.*		Copper. Ingot.
1895.....	$9,220	15,048	$30,290	$6,305	$68,220	$2,815	39,125	$147,395	368	$510	(*c*)
1896.....	18,980	(*c*)	70,845	19,340	87,485	7,585	71,680	197,515	(*c*)	2,485	$8,375
1897.....	23,985	47,457	81,305	12,120	101,320	16,365	139,369	474,690	(*c*)	10,825	1,695
1898.....	22,835	52,077	96,890	14,350	66,305	10,090	134,315	421,230	7,936	5,340	2,110
1899.....	12,320	40,741	90,320	8,945	62,445	4,640	129,512	475,720	*d* 1,456	9,840	2,805
1900.....	16,135	33,586	71,925	7,785	85,565	9,115	152,013	553,495	(*c*)	76,295	1,800

Year.	Copper.—*Continued.* Rod, Sheet, and Wire.	Copper Sulphate.	Glass and Glassware	Gold Coin.	Gold and Silver Leaf.	Iron. Pig.		Iron. Galvanized. (Corrugated Sheet.)		Iron. Other Manufactures.
1895.....	$4,335	$455	$64,410	$4,540,000	$2,765	289	$8,870	3,848	$289,985	$280,670
1896.....	9,440	735	103,210	4,751,850	2,565	639	12,455	7,467	525,050	771,945
1897.....	12,295	625	137,815	225,000	2,505	953	14,095	11,689	897,035	661,630
1898.....	18,695	895	86,740	675,000	4,265	1,431	20,620	8,997	685,575	631,145
1899.....	15,515	(*c*)	105,890	25,000	1,905	1,379	25,345	4,280	341,770	649,735
1900.....	23,455	(*c*)	85,835	(*c*)	2,445	2,565	47,950	9,455	745,570	893,295

Year.	Iron and Steel Wire.	Steel.	Lead—Sheet, Pig and Pipe.		Paraffine Wax.	Petroleum and Turpentine. *No. of Gallons.*		Plaster of Paris.		Quicksilver. *No. of Flasks.*	
1895.....	$53,995	$21,765	96	$6,040	$2,640	495,024	$82,730	52	$1,050	323	$9,880
1896.....	67,715	82,935	321	20,250	3,780	853,649	159,765	245	3,545	840	20,285
1897.....	82,545	80,340	537	37,115	3,750	1,058,022	163,735	496	6,225	623	22,705
1898.....	97,580	64,195	469	27,240	8,510	1,165,375	195,635	246	2,725	691	25,280
1899.....	83,735	1,007,825	146	8,125	9,005	1,241,159	191,180	62	970	(*c*)	37,900
1900.....	99,470	1,533,000	1,646	81,050	9,555	1,501,664	248,920	36	570	(*c*)	28,695

Year.	Salt. Rock. *No of Sacks*		Salt. Other Kinds.		Silver Coin.	Sodium Salts. Carbonate. (Crystals.)		Sodium Salts. Hydrate.	Sodium Salts. Other Salts Inc. Potash.	Stone. Grindstones. *Number.*		Stone. Marble and other kinds
1895.....	212	$595	833	$9,710	$92,000	(*c*)	$1,270	$2,460	$1,240	*b*700	$660	$7,140
1896.....	(*c*)	260	997	10,090	147,095	(*c*)	2,150	2,420	4,940	(*c*)	2,055	22,070
1897.....	(*c*)	410	1,211	11,568	103,000	143	2,780	3,955	4,940	(*c*)	2,445	20,190
1898.....	332	275	1,346	12,665	1,050	137	2,390	5,510	6,505	1,206	1,140	19,190
1899.....	(*c*)	205	1,567	14,290	5	(*c*)	.....	(*c*)	(*c*)	(*c*)	1,085	18,250
1900.....	(*c*)	350	1,596	15,965	17,390	(*c*)	.....	(*c*)	(*c*)	(*c*)	770	11,230

Year.	Sulphur. *No. of Casks.*		Tin. Ingot.	Tin. Block, Foil, Plate, and Wares.	Whiting.	Zinc, Sheet and Ingot.
1895.....	344	$1,230	(*c*)	$15,900	$1,065	$3,970
1896.....	(*c*)	720	$4,090	34,395	1,950	6,295
1897.....	(*c*)	600	6,360	24,835	1,530	7,565
1898.....	283	970	6,490	19,150	1,625	7,710
1899.....	(*c*)	1,295	13,235	*e*4,900	1,530	16,530
1900.....	(*c*)	3,940	13,165	23,410	1,755	8,860

(*a*) From the *Blue Books for Western Australia*, except the figures for 1896, which are from the *Annual Report of the Collector of Customs*, wherein only the values of the imports are stated. (*b*) Number of packages. (*c*) Not stated in the reports. (*d*) Metric tons. (*e*) Foil and plate only.

MINERAL EXPORTS OF WESTERN AUSTRALIA. (*a*) (IN METRIC TONS AND DOLLARS; £1 = $5.)

Year.	Coal.		Copper Ore.		Gold. Bullion—Kg.		Gold. Coin.	Iron and Steel.	Lead Ore.	Mica.	Tin Ore.	
1895.....	15,095	$92,675	839	$64,760	7,201	$4,398,740	$460	.....	(*b*)	.....	$15	281	$48,510
1896.....	(*b*)	75,205	(*b*)	500	8,748	5,344,040	(*b*)	$130	(*b*)	.....	(*b*)	(*b*)	21,695
1897.....	23,756	129,010	86	5,165	20,994	12,824,885	3,130,400	4,165	(*b*)	$20	1,045	96	16,370
1898.....	26,240	149,135	361	21,330	32,633	19,953,490	75,000	41,000	5	165	(*b*)	69	13,805
1899.....	45,283	220,415	2,023	207,260	44,587	27,256,840	398,460	88,790	16	480	250	313	115,810
1900.....	79,706	417,105	859	82,300	41,658	18,995,620	8,753,815	33,270	(*b*)	1,210	15	478	190,895

(*a*) From the *Blue Books for Western Australia*, except the figures for 1896, which are from the *Annual Report of the Collector of Customs*, Perth. In 1896 there were also exported brassware, $320; silver plate, $85; and salt, $80. (*b*) Not stated in the reports.

ASSESSMENTS LEVIED BY MINING COMPANIES.—*Continued.*

Name of Company.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	Total Levied.
Good Title, g., Cal.						$20,000				$20,000
Gould Central Oil, Cal.									$5,000	5,000
Gould Oil, Cal.									25,000	25,000
Gould & Curry, s., Nev.	$80,200	$32,400	$48,600	$48,600	$59,400	37,800	$49,400	$54,800	43,200	4,786,450
Grand Prize Oil, Cal.									20,000	20,000
Granite Hill, g.s., Cal.							3,000			3,000
Grape Vine Canyon, g.s., Cal.							10,000	14,000	10,000	34,000
Great Bonanza, g.s., Utah.								5,000		5,000
Great Eastern, g.s., Utah.						1,500	1,500	1,500		4,500
Great Western, q., Cal.						5,000	20,000			75,520
Grizzly, g.s., Cal.						1,500		5,000		6,500
Hale & Norcross, s., Nev.							39,200	22,400	11,200	5,751,080
Hanford-Fresno Oil, Cal.										24,140
Hanford-Sanger Oil, Cal.									6,000	6,000
Head Center Con., g.s.c., Ariz.							25,125			25,125
Hercules, g.s., Utah.								20,000		20,000
Hester A., g.s., S. Dak.								500		3,000
Highland, g.s., Utah.								8,000		8,000
Highland(Leadville), g.s.,Colo.								125,000		125,000
Hilda Gravel, g.s., Cal.						2,000		2,000		4,000
Hillside, g.s., Utah.							1,500			1,500
Himalaya, g.s., Utah.							5,000			5,000
Home, g.s , Cal.						3,000		10,000		13,000
Homestake, g.s., Utah.						4,000	4,000			12,000
Horn Silver Tunnel, g.s., Utah.							500	500		1,000
Horsefly, g., Cal.						8,000			10,000	18,000
Horseshoe Bar Con., g.s., Cal.						6,000	3,000	1,200	600	87,800
Humboldt, g.s., Cal.							2,000			2,000
Imperial Oil, Cal.									2,000	2,000
Imyo Marble, Cal.									5,000	17,000
Independence, g.s., Utah.							6,000	9,000		15,000
Independent, g., Cal.									10,000	10,000
Ingot, g.s.l., Utah.									10,000	10,000
International, g.s., Utah.							1,500			1,500
Jefferson, g.c., Utah.								1,500	1,750	3,250
Jennie Lind, g.s., Cal.							1,000	2,000	8,000	11,000
Joe Bowers, g.s.. Utah.								14,000	21,000	35,000
Joe Bowers Ext., g.s., Utah.								15,000		40,500
Julia Con., s., Nev.	5,000		5,500	5,500	5,500		3,300	3,300		1,501,800
Jumbo, g.s., Utah.						500				500
Junction, g.s., Cal.						10,500	6,000			16,500
Jupiter Gravel, g., Cal.					40,000	40,000				80,000
Justice, s., Nev.						10,500	21,000	15,750	21,000	3,704,500
Karan, g., Cal.						2,500				2,500
Karl Brown Oil, Cal.									15,000	15,000
Kate Hayes, g.s., Cal.						10,000	10,000			70,000
Kentuck, g., Utah.						30,000				30,000
Kentuck Con., s., Nev.	10,500	26,250	10,500	5,250	10,500	5,250		3,150		128,450
Kern River Oil, Cal.									40,000	40,000
Kern Sunset Oil, Cal.									2,000	2,000
Kings County Oil, Cal.									6,000	6,000
Lady Washington, s., Nev.				5,400			5,400			163,200
La Grange, g.s., Cal.							15,000			15,000
Laird, g., Cal.						10,000				10,000
Larkin, g.s., Cal.						2,000	2,000	4,000	10,000	28,000
La Suerte, g.s., Cal.						7,500	7,500	7,500	5,000	27,500
Leon, g., Cal.						1,500				1,500
Linda Vista Oil, Cal.									11,460	11,460
Lion Con., g.s., Utah.							500	500		1,000
Little Bell, g., Utah.									37,500	37,500
Little Chief, g.s., Utah.							8,000	12,000	16,000	36,000
Little Pittsburg, g.s., Utah.			4,000	6,000	4,000	4,000	5,000			23,000
Live Oak Con., g.s., Cal.						20,000	10,000	10,000		40,000
Live Yankee, g.s., Cal.						5,000	2,000			7,050
Lombard, g.c., Utah.									1,250	1,250
Louis, S., g., Utah.									10,000	10,000
Lower Mammoth, g.s., Utah.						12,500	15,000	15,000		42,500
Lucky Bill, g.s., Utah.				7,200	6,600	1,800	2,500	2,400	12,000	73,000
Lulah Con., g.s., Utah.							1,500			1,500
Mammoth Garfield, g.s., Cal.								17,500		17,500
Maple Creek, g., Cal.									10,000	10,000
Maple, g.s., Utah.									3,000	3,000
Marguerite, g.s., Cal.					20,000	15,000	15,000			35,000
Marina Marsicano, g.s., Cal.					16,360	19,000	19,000	7,000	1,000	62,360
Mariposa Com'l&M'g,g.s.,Cal.								50,000	50,000	210,000
Martha Washington,g.s.,Utah.						3,000	6,000	6,000	9,000	24,000
Martin White, s., Nev.	25,000	25,000					120,000			1,200,000
Maxfield, g.s., Utah.						6,000	9,000	9,000		24,000
Mayday, g.s., Cal.						5,000	10,000	5,000	2,500	22,500
Mayday, g.s., Utah.						2,000	2,000			4,000
Mayflower Gravel, g.s., Cal.						6,000		7,500	6,000	19,500
Mayflower, g.s., Utah.								2,000	5,000	7,000
Mazeppa, g.s., Cal.								5,000		5,000
McKittrick, Con., Oil, Cal.								18,00	18,000	30,500

ASSESSMENTS LEVIED BY MINING COMPANIES.—*Continued.*

Name of Company.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	Total Levied.
McKittrick Oil, Cal.									$15,000	$15,000
Melcher, g.s., Utah								$2,000	1,250	3,250
Merrimac, g., Cal.						$20,000				20,000
Meteor, g.s., Utah						3,734	$4,999	2,907	1,980	13,620
Mexican, s., Nev.	$76,500	$75,600	$75,600	$40,320	$20,000	40,320	25,200	45,360	50,400	2,409,920
Midland, g s., Utah								3,000		3,000
Midnight Bowers, g.s., Utah							1,000	1,000		2,000
Minnehaha Oil, Cal.									10,000	10,000
Mohican g., Cal.									10,000	10,000
Molly Bawn, g.s., Utah							1,000			1,000
Montecito, g., Cal.						10,000				10,000
Montreal, g.s., Utah			375		375		25,000			30,625
Mooney Con., g.s., Cal.								20,000		20,000
Morgan, g., Cal.						10,000				10,000
Mountaineer, g.s., Cal.						15,000		25,000		40,000
Mountain View, g., Cal.									15,000	15,000
Mt. Blanc Con., g., Cal.									1,250	1,250
Mt. Diablo Oil, Cal.									10,000	60,000
Nancy Hanks, g. Cal.						5,000				5,000
Nashville, g., Cal.						2,000				2,000
National Con., g.s., Cal.						15,000	45,000	15,000	10,000	78,695
Navajo, g.s., Utah									2,500	2,500
Nevada, s., Nev.								10,000		10,000
New Century Oil, Cal.									15,000	15,000
New Erie, g.s., Utah							2,000	500	7,500	10,000
New Imperial, g.s., Utah							1,000			1,000
New Klondike, g.s., Utah							2,961	235		3,196
New La Plata, g.s., S. Dak.								300		1,700
New Southern Cross, g., Mont.									5,000	5,000
New State, g.c., Utah								1,500		4,500
Nineteen Oil, Cal.									6,000	6,000
North Bloomfield, g., Cal.						25,000				25,000
North Bonanza, s., Nev.								15,000		255,000
North Gould & Curry, s., Nev.	10,000	20,000		10,000		20,000				375,000
North Mercur, g., Utah						10,000				10,000
North Rapidan, s., Nev.								8,000		8,000
Northern Light, g.s., Utah						8,000		8,000	18,000	34,000
Northern Spy, g.s., Utah						10,000	10,000			20,000
Nugget Placer, g., Cal.									10,000	10,000
Occidental Con., s., Nev.	55,000	30,000	30,000	65,000	30,000	20,000	20,000	5,000	10,000	534,179
Okanogan, g., Wash.								10,566		10,566
Old Bonanza, g.s., Cal.							2,500			2,500
Old Colony & Eureka, g.s., Utah								2,500		2,500
Old Home, g.s., Cal.						5,000	3,500	3,500	1,000	13,000
Old Susan, g.s., Utah								7,500	500	8,000
Omaha Con., g.s., Cal.						10,000	25,000	100,000		135,000
Omaha, g.s., Utah								6,000		6,000
Ophir, s., Nev.	100,000	100,000	100,000	25,200	25,200	43,200	50,400	60,480	45,360	4,758,808
Opohonga, g.s., Utah						1,500	1,000			2,500
Orient, g.s., Cal.							50,000	75,000	35,000	160,000
Orient, g., Utah									2,500	2,500
Orleans, g.s., Cal.						15,000	12,000		5,000	32,000
Oro Quartz, g.s., Cal							4,500			4,500
Osceola Con., g.s., Cal.						1,000	1,000	2,000	2,000	15,810
Overman, s., Nev.	60,000	34,560	23,040	34,560	17,280	17,280	11,520	17,268	23,040	4,181,430
Pacific, g.s., Utah							500	750		1,250
Park City & Mid. Sun, Utah								10,000		10,000
Peabody, g.s., Cal.								10,000		10,000
Petroleum Center Oil, Cal.									61,500	82,000
Phœnix, g.s., Utah					1,000			1,000		2,000
Picnic, g.s., Utah								1,000		1,000
Potosi, s., Nev.	84,000	112,000	56,000	28,000	50,400	50,400	39,200	39,200	28,000	2,263,600
Powning, g.s., Cal.							2,500			2,500
Prior Hill, g.s., S. Dak.								200		1,000
Prosperity Oil, Cal.									25,000	25,000
Providence, g., Cal.									20,000	20,000
Provident Oil, Cal.									7,500	7,500
Queen Esther Oil, Cal.									5,000	5,000
Quincy, g., Cal.							10,000	20,000		30,000
Raven Oil, Cal.									10,500	10,500
Raymond, g., Utah									12,500	12,500
Red Bank Oil, Cal.									6,000	6,000
Red Cap, g., Cal.						90,000				90,000
Reddick, g.s., Cal.						5,000	5,000			10,000
Red Jacket, s., Nev.							2,000			2,000
R. G. W., g.s., Utah							2,000	1,000	2,500	5,500
Rescue Gold, Nev.					3,000	2,000	500			5,500
Revenue, g.s., Utah							4,500			4,500
Reward, g.s., Cal.					7,040	3,840	3,200	9,920	14,500	91,500
Rich Bar Gravel, g.s., Cal.								6,000		6,000
Richmond, g., Cal.						10,000				10,000
Ridge & Valley, g.s., Utah								5,000	10,000	15,000
Roberts Oil, Cal.									3,000	3,000
Rockland, g., Cal.						3,000				3,000

ASSESSMENTS LEVIED BY MINING COMPANIES.—*Concluded.*

Name of Company.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	Total Levied.
Rose Creek, g.s., Cal.						$5,000	$5,000			$10,000
Ruby Hill, g.s., Utah								$600	$1,000	1,600
Sacramento, g.s., Utah							600		2,500	3,100
Sailor Con., g.s., Cal.							11,000	6,000	3,000	20,000
Salmon River, s., Nev.							1,425			11,970
Salt Lake & Nev., g.s., Utah						1,000			2,500	3,500
Santa Rosalia, q., Mex.								5,000		5,000
Savage, s., Nev.	112,000	100,805	$67,200	$67,200	$67,200	44,800	22,400	33,600	22,400	7,366,000
Scorpion, s., Nev.		5,000			5,000			3,000		448,000
Sea Breeze Oil, Cal.									20,000	20,000
Sea Swan, g., Utah									2,500	2,500
Seg. Belch. & Mides, s., Nev.	35,000	20,000	30,000	10,000	10,000	8,000	10,000	6,000	6,060	390,000
Sharp, g., Utah									5,000	5,000
Shasta Oil, Cal.									20,000	20,000
Sheba, g.s., Cal.								10,000		10,000
Sheep Rock, g.s., Utah					5,250			52,500		57,750
Shoebridge Bonanza, g.s., Utah								3,200	4,000	13,600
Shower Con., g.s., Utah							8,000	2,000	24,000	34,000
Sierra Nevada, s., Nev.	45,000	50,000	50,000	50,000	40,000	20,000	50,000	45,000	50,000	6,851,910
Silver Bell, s., Mont.						5,000				5,000
Silver Bow, g.s., Utah								5,000	7,500	12,500
Silver Cloud, g.s., Utah							5,000		2,500	7,500
Silver Hill, s., Nev.	5,400	5,400			5,400	5,400				2,220,200
Silver King, g.s., Ariz.		100,000		75,000	50,000	50,000	50,000	25,000	25,000	515,000
Silver Park, g.s., Utah								9,000		9,000
Silver Queen, g.s., Utah								1,000		1,000
Silver State, g.s., Utah					1,000			500		1,500
Siskiyou Con., g.s., Cal.	9,000	14,000	4,000	2,000		3,000	3,000	6,000		55,000
Skagit Cumb. Coal, Wash.								7,500	22,500	29,500
Skylark, c., Utah									5,000	5,000
Snow Flake, g.s., Utah						2,000	5,000	2,000	7,000	23,500
Sonora Quartz, g.s., Mex.								5,000		5,000
South Bingham, g.s., Utah							2,500	2,500		5,000
South Eureka, g.s., Cal.							6,000			6,000
South Fork Con., g.s., Utah						5,000				5,000
South Paloma, g.s., Cal								1,200		1,200
South Sliger, g., Cal.									10,000	10,000
Spanish Bar, g.s., Cal.						2,000	5,000	11,000	5,000	23,000
Star, g.s., Utah						5,000	30,000	25,000		66,000
Sterling, g., Cal.						15,000				15,000
Success, g.s., Utah							9,750	3,000		12,750
Sunbeam Con., g.s., Utah					11,250	5,000	50,000	55,000		131,383
Sweet Vengeance, g.s., Cal.								10,000		130,000
Tanama, g.s., Cal.							10,000		30,000	40,000
Tesora, g.s., Utah								2,750	80,000	102,000
Tetro, g.s., Utah						18,000	15,000	15,000	27,000	78,500
Texas, g.s., Cal.							15,000	30,000	10,000	55,000
Thorpe, g.s., Cal.						5,000	5,000			10,000
Tintic, g.s, Utah							4,375			4,375
Tomboy, g., Utah										5,000
Tracy, g.s., Cal.							5,000			5,000
Troy, g.s., Alaska					2,000	6,250	6,250			16,750
Tuscarora Chief, g.s., Utah							2,000			2,000
Ukiah Oil, Cal.									10,000	10,000
Union Con., s., Nev.	45,000	35,000	20,000	40,000	20,000	30,000	18,000	30,000	25,000	2,715,000
United Sunbeam, g., Utah									30,000	30,000
U. S. Grant, g.s., S. Dak.								1,000		4,500
Utah Con., s., Nev.	25,000	5,000	5,000	10,000	30,000	20,000	15,000	15,000	20,000	520,000
Valeo, g.s., Utah							10,000	10,000		20,000
Vallejo, q., Cal.						2,000	2,000			4,000
Valley View Oil, Cal.									17,500	17,500
Vernon Oil, Cal.									25,000	25,000
Victor, g.s., Utah				375				15,000	5,000	26,000
Victoria, g.s., Utah								4,000		4,000
Victory, g.s., S. Dak.								200		2,825
Wasatch, Utah									6,000	6,000
Washington Con., g.s., Wash.								200		2,000
Washington Oil, Cal.									7,000	7,000
Watt Blue Gravel, g.s., Cal.							3,000			58,000
Wellington Oil, Cal.									70,000	70,000
West Argent, Utah									10,000	10,000
West Lake Oil, Cal.									10,000	10,000
West Morn'g Glory, g.s., Utah								1,250	1,250	7,250
West M't'n Placer, g.s., Utah								8,000	3,750	11,750
Willietta, g., Cal.									10,000	10,000
Wisconsin Oil, Cal.									25,000	25,000
Yankee Con., g.s., Utah							2,500	5,000	10,000	17,500
Yankee Girl, g.s., Utah							5,000			5,000
Yellow Jacket, s., Nev.	90,000	90,000	90,000	90,000		24,000	36,000	42,000	36,000	5,904,000
Young America, g.s., Utah								8,000		8,000
Yuba Con., g., Cal.						2,500			45,000	47,500
Zacca Lake Oil, Cal.									1,875	1,875
Zuba, g., Cal						5,000				5,000

c., copper; g., gold; i., iron; l., lead; q., quicksilver; s., silver; z., zinc.

AUSTRALASIA.

THE most important articles of mineral production in the seven colonies of Australasia are gold, silver, lead, copper, tin, iron and coal. These industries are referred to specifically under the respective captions elsewhere in this volume. The statistics of production, imports and exports as reported in the official statistics are summarized in the following tables:

MINERAL PRODUCTION OF NEW SOUTH WALES. (*a*) (*c*) (IN METRIC TONS AND DOLLARS; £1—$5.)

Year.	Alunite.		Antimony and Ore.		Bismuth.		Chrome Ore		Clay. (Fire.)		Coal.		Cobalt Ore.		Coke.	
1896....	1,393	$20,580	135	$9,170	41	$2,450	3,913	$56,400	35	$345	3,972,068	$5,627,405	.....	.....	26,778	$109,255
1897....	736	10,860	172	18,060	8	4,000	3,433	51,345	....	.....	4,453,729	6,150,205	.....	.....	65,229	226,960
1898....	2,988	44,115	84	4,580	30	23,075	2,145	31,505	15	160	4,781,551	6,359,163	119	2,800	33,538	324,674
1899....	935	13,815	332	13,470	16	16,775	5,327	87,080	27	330	4,670,580	6,628,995	193	4,495	98,074	395,650
1900....	1,946	28,725	252	12,145	11	28,200	3,338	59,135	29	545	5,595,879	8,344,555	145	7,950	128,238	548,100

Year.	Copper Ingot.		Copper Ore and Regulus.		Gold—Kg.		Iron. (*b*)		Iron Oxide		Lead, Argentiferous.			
											Metal	Ore.	Value.	
1896....	4,594	$1,001,180	15	$375	9,221·2	$5,366,800	4,798	$166,415	381	$4,005	19,886	271,640	$8,794,665	
1897....	6,864	1,499,145	169	4,255	9,088·9	5,442,065	3,291	109,310	284	2,680	18,395	275,249	8,407,640	
1898....	5,744	1,400,240	181	4,195	10,590·4	6,223,649	5,283	211,250	398	4,160	10,270	394,676	8,223,895	
1899....	4,715	1,650,600	1,358	348,470	15,433·3	8,759,075	6,604	277,500	402	4,230	20,614	431,126	9,968,790	
1900....	5,712	1,975,515	1,494	164,665	10,801·6	5,972,605	7,101	305,420	318	3,430	19,400	426,480	12,569,370	

Year.	Lead, Pig.		Manganese Ore.		Opal—Kg.		Platinum. Kg.		Shale, Oil.		Silver—Kg.		Stone.	
													Limestone Flux	
1896....	24	$1,295	..	.....	630·4	$125,000	75·8	$17,395	32,348	$171,010	6,307	$132,590	90,846	$271,305
1897....	32	1,990	..	.....	2400·4	475,000	61·2	14,745	34,635	203,060	4,666	83,555	68,671	208,990
1898....	1,745	96,410	1	$25	.....	400,000	38·9	10,310	30,164	159,170	16,580	296,390	9,401	28,915
1899....	(*d*) 4,896	498,945	*Nil*	.....	.....	675,000	19·8	5,350	37,307	204,115	21,525	384,565	1,016	3,750
1900....	(*d*) 6,807	695,730	18	2 0	.....	400,000	15.6	5,035	23,229	103,260	24,080	451,215	17,273	19,810

Year.	Tin, Ingot.		Tin Ore.		Zinc Ore.		Sundry Minerals
1896....	1,737	$496,060	98	$14,525	.....	.....	$4,620
1897....	1,159	350,640	14	2,800	29,308	$118,440	37,160
1898....	908	302,825	1	175	39,564	144,705	10,105
1899....	895	490,690	5	1,450	50,677	246,085	24,850
1900....	915	600,160	15	4,500	20,594	220,930	555,245

(*a*) From the Annual Report of the Department of Mines and Agriculture, New South Wales. (*b*) Manufactured from old iron. (*c*) In addition to the above there is a small output of diamonds, which amounted to 56,352 carats ($156,965) for the ten years preceding 1898. (*d*) Includes carbonate and chloride.

MINERAL IMPORTS OF NEW SOUTH WALES. (a) (IN METRIC TONS AND DOLLARS; £1—$5.)

Year.	Brass. (Yellow Metal.)	Cement—*Barrels.*		Chrome Ore.		Coal.		Coke.		Copper. In Matte and Regulus.	
1896....	$92,895	126,242	$239,025	5,537	$109,220	807	$4,870	43,824	$675,585	93	$19,380
1897....	69,390	184,881	403,210	2,731	49,240	1,755	6,055	33,970	511,980	42	8,680
1898....	102,250	183,851	418,580	1,780	82,770	666	2,985	4,064	61,735	.....	.....
1899....	142,945	247,398	622,245	4,009	63,380	2,453	6,530	433	8,080	91	16,755
1900....	194,500	177,076	455,455	279	4,125	2,743	20,205	516	10,750	22	1,275

Year.	Copper—*Continued.* Ingot.		Ore.		Rod, Sheet, and Wire.	Gold. Coin.	Bullion and Ores.	Iron and Steel. Pig.		Ore.		Manufactures. (c)	
1896....	5	$1,085	315	$12,875	$37,895	$2,407,100	$9,943,755	2,195	$124,255	108	$555	67,978	$3,626,075
1897....	6	1,585	1,401	92,440	96,445	5,749,095	10,398,540	16,256	269,470	1,298	8,095	71,469	3,904,105
1898....	3	1,000	1,018	40,245	61,635	18,323,980	9,779,270	12,061	169,885	2,688	8,595	65,140	3,621,285
1899....	43	11,560	9,209	346,500	135,370	3,510,800	12,908,555	9,153	168,395	4,205	14,615	89,957	5,224,515
1900....	35	12,400	7,078	366,470	239,605	7,212,835	12,729,040	13,280	333,130	6,350	20,545	86,838	6,203,885

Year.	Lead. Pig.		Pipe, Sheet and Old.		Nickel Ore.		Petroleum, Refined. *Liters.*		Potassium Salts. Nitrate.		Quicksilver. *Flasks.*	
1896....	7,440	$362,720	268	$19,720	3	$120	9,538,367	$488,375	162	$19,905	261	$9,250
1897....	5,281	289,590	308	20,235	208	5,000	11,027,291	492,275	176	18,455	470	12,255
1898....	2,379	135,330	49	3,685	788	7,575	13,723,963	563,690	181	17,170	469	17,005
1899....	1,963	125,580	75	6,145	(b)	.....	17,335,661	883,255	114	11,115	398	17,010
1900....	5,787	444,560	29	3,705	508	10,300	16,897,928	907,900	122	13,565	228	10,425

Year.	Salt. Rock.		Brine. *Bags.*		Silver. Coin.	Ingot—Kg.		In Matte—Kg.		Ore.		Slate. Roofing—*Number*	
1896....	7,275	$39,825	25,784	$207,560	$49,000	180	$3,900	3,958	$79,245	15,073	$672,770	2,219,681	$90,595
1897....	4,654	34,110	36,722	261,230	131,630	288	5,060	1,928	35,500	1,288	38,680	1,908,475	78,990
1898....	8,647	59,220	30,991	217,115	286,010	267	4,980	.....	.....	964	37,625	1,893,871	90,240
1899....	7,967	46,430	34,537	231,740	354,185	299	5,975	1,045	18,715	3,070	95,045	2,835,637	113,690
1900....	3,662	23,120	23,805	210,790	810,480	342	6,955	132	2,370	1,880	83,445	2,950,980	96,025

Year.	Slate—*Cont'd.* Slabs. *Number.*		Sodium Salts. Bicarbonate.		Carbonate. (Crude.)		Carbonate. (Crystals.)		Hydrate. (Caustic.)		Stone, Excepting Marble.
1896....	3,602	$11,675	611	$25,080	1,749	$60,800	745	$18,305	1,010	$48,465	$40,925
1897....	2,605	8,575	788	31,395	1,452	50,583	495	7,940	1,213	66,900	27,065
1898....	3,492	12,430	953	36,495	1,469	38,905	468	13,440	1,241	63,225	30,235
1899....	5,307	13,135	1,200	39,080	1,716	42,525	566	19,375	1,209	61,680	31,065
1900....	10,176	20,230	979	32,475	1,341	39,755	185	5,180	1,492	81,765	46,520

Year.	Sulphur.		Tin. Ingot.		Ore.		Plates.	Zinc. Slabs.		Sheet and Manufactures.	
1896....	1,330	$22,235	910	$265,505	1,073	$169,875	$353,345	1,416	$116,115	368	$35,500
1897....	2,287	33,955	698	205,135	662	104,510	200,350	1,341	122,815	561	58,010
1898....	1,845	26,960	478	161,245	554	92,665	373,060	1,220	122,325	377	43,905
1899....	1,575	23,575	681	396,095	868	262,455	258,085	724	90,720	225	35,005
1900....	2,208	56,510	299	195,205	741	254,710	643,940	1,084	122,325	514	73,000

(a) From the *New South Wales Statistical Register.* (b) Not stated in the reports. (c) In addition there were imports of manufactures for which no weights are stated; in 1897, $68,495; 1898, $136,640; 1899, $86,690 and in 1900, $96,205.

MINERAL EXPORTS OF NEW SOUTH WALES. (a) (e) (IN METRIC TONS AND DOLLARS; £1 — $5.)

Year.	Antimony. Ore.		Auriferous.		Metal.		Bismuth Ore.	Cement. *Barrels.*		Chrome Ore.	Coal.		Cobalt Ore.	
1896..	87	$2,810	25	$3,160	23	$3,200	45·0	$3,350	33,987	$74,650	9,465	$145,165	2,514,506	$4,501,320	284	$9,750
1897..	49	2,510	21	1,500	102	14,050	d3·3	4,150	15,272	39,185	5,959	101,320	2,739,769	4,760,270	73	2,500
1898..	57	2,150	13	795	13	1,570	31·5	23,775	16,801	45,420	6,924	122,775	2,836,465	4,818,340	164	4,450
1899..	314	11,820	18	1,650	1	20	15·8	16,775	12,297	36,030	9,795	167,930	2,843,310	5,028,970	347	11,095
1900..	258	12,680	(c)	.....	1	175	7·3	9,785	9,987	26,680	3,618	68,635	3,424,366	6,365,170	148	8,000

Year.	Coke.		Copper. Ingot.		Copper. In Matte.		Copper. Ore.		Copper. Rod, Sheet, Wire.	Gold. Ore.	Gold. Coin.
1896....	5,521	$22,615	4,026	$904,540	595	$117,595	15	$375	$8,000	$488,425	$18,014,980
1897....	32,221	135,225	4,126	964,880	2,778	549,440	169	4,255	5,770	282,040	21,733,235
1898....	31,284	125,330	5,285	1,235,715	460	114,765	181	4,196	12,950	237,410	32,645,800
1899....	43,706	181,960	5,532	1,936,700	1,163	397,660	482	17,710	21,245	13,970	17,446,430
1900....	75,598	302,755	6,771	2,341,985	626	129,195	867	35,470	13,885	19,705	26,949,110

Year.	Gold—*Continued.* Bullion—Kg.		Iron and Steel. Pig Iron.		Iron and Steel. Manufactures. (*b*)		Lead. Pig.		Lead. Pipe and Sheet.		Lead. Argentiferous.		Nickel Ore.	
1896....	2,576	$1,417,580	1,470	$26,350	17,289	$1,089,375	3,150	$167,425	750	$52,535	19,897	$3,974,335	(*c*)	.....
1897....	3,295	2,043,690	1,183	22,495	19,515	1,297,320	2,100	119,395	1,043	77,725	18,395	3,227,385	203	$4,900
1898....	3,326	2,022,925	1,294	31,060	15,454	1,021,015	3,367	191,210	707	57,945	10,271	1,606,680	785	9,800
1899....	7,209	4,614,655	639	12,785	16,550	1,176,695	4,865	333,235	1,389	125,160	20,582	2,023,640	71	840
1900....	3,980	2,302,390	885	22,125	18,269	1,415,415	7,362	573,415	1,420	136,525	18,277	1,794,320	(*c*)	.....

Year.	Salt. Rock.		Salt. Brine—*Bags.*		Silver. Coin.	Silver. In Matte—Kg.		Silver. Ore.		Sodium Salts. Bicarbonate.		Sodium Salts. Carbonate. (Crude.)	
1896....	457	$3,605	2,820	$32,440	$66,450	7,550	$152,960	284,524	$5,447,925	39	$1,790	207	$7,010
1897....	330	3,065	4,752	58,380	99,545	2,454	41,860	275,807	5,205,525	61	2,795	117	4,010
1898....	433	3,635	5,166	60,445	149,360	8,794	152,655	396,057	6,684,955	124	5,580	285	9,595
1899....	315	2,520	5,491	59,985	312,475	17,583	312,665	432,520	7,901,180	105	3,915	139	4,145
1900....	393	3,600	2,904	30,595	303,590	27,887	519,500	428,615	10,816,160	117	4,215	217	6,640

Year.	Sodium Salts—*Continued.* Hydrate. (Caustic.)		Sodium Salts—*Continued.* Nitrate.		Stone.	Sulphur.		Sulphuric Acid.		Tin. Ingot.		Tin. Ore.		Tin. Plate.
1896....	148	$7,545	17	$790	$7,015	139	$4,240	100	$5,585	2,646	$763,595	99	$14,525	$79,100
1897....	90	4,660	6	5,730	3,545	32	1,800	52	3,495	1,837	556,345	143	2,800	78,205
1898....	132	6,530	42	4,365	3,505	38	1,565	24	1,390	1,384	481,925	1	175	55,040
1899....	297	12,725	37	1,840	5,575	102	4,175	43	2,460	1,876	1,108,735	7	2,225	141,560
1900....	191	11,490	20	2,300	7,040	99	4,215	53	3,750	1,777	1,159,035	15	4,500	122,770

(*a*) From the *New South Wales Statistical Register.* (*b*) Values including those of manufactures for which no quantity is stated, as follows: In 1896, $17,970; 1897, $9,125; 1898, $14,445; 1899, $13,150 and in 1900, $9,810. (*c*) Not stated in the reports. (*d*) Probably bismuth metal. (*e*) There was also exported from N. S. W. in 1897, iron oxide: 246 metric tons, $2,830, and iron ore, 5 metric tons, $35.

MINERAL PRODUCTION OF NEW ZEALAND. (*a*) (*b*) (IN METRIC TONS AND DOLLARS; £1 = $5.)

Year.	Antimony Ore.		Coal.		Coke.		Gold—Kg.		Manganese Ore.	
1896.....	21	$2,250	805,537	$2,143,240	107	$1,315	8,202	$5,207,140	66	$1,025
1897.....	10	785	854,164	2,259,575	14	.....	7,827	4,901,020	183	2,705
1898.....	*Nil.*	.....	921,546	2,378,655	9	.....	8,714	5,403,445	220	3,515
1899.....	*Nil.*	.....	990,838	2,488,085	18	45	12,117	7,565,865	137	2,035
1900.....	3	505	1,111,860	2,734,975	*Nil.*	.....	11,675	7,198,010	166	2,940

MINERAL PRODUCTION—*Continued.*

Year.	Mixed Ores. Unspecified.		Silver—Kg.	
1896.....	38	$6,675	2,933	$52,945
1897.....	1,586	29,460	5,716	104,860
1898.....	1,857	23,960	9,140	165,535
1899.....	1,330	32,945	10,866	204,190
1900.....	2,126	63,755	10,202	200,360

MINERAL IMPORTS. (*c*) (IN METRIC TONS; £1—$5.)

Year.	Coal.		Machinery.	Railway Materials.	Tools and Implements.
1896.....	103,384	$470,690	$1,417,200	$163,270	$350,690
1897.....	112,681	490,695	2,005,265	682,855	450,905
1898.....	117,274	526,115	2,349,315	499,985	555,755
1899.....	101,259	464,075	2,267,075	636,820	465,100
1900.....	126,059	602,030	2,936,830	1,007,960	645,385

(*a*) From *New Zealand Mines Statements*, by the Hon. A. J. Cadman, Minister of Mines, Wellington. (*b*) The exports are stated to be identical with the production, except in the case of coal, of which substance the exports were as follows: In 1896, 80,796 tons, value, $359,920; in 1897, 77,280 tons, value, $347,975; in 1898, 57,333 tons, value, $251,905; in 1899, 90,912 tons, value, $415,425; in 1900, 116,216 tons, value, $497,870. (*c*) From *British Statistical Abstracts.*

Year.	Lime. (Hydraulic and Caustic.)		Manganese Ore.		Millstones.		Mineral Paints.		Nickel, Bars, Sheets, Wires, Etc.		Nickel and Cobalt Ores.	
1896.....	76,895	$351,238	701	$8,696	1,831	$109,842	1,700	$95,826	273	$273,640	113	$9,278
1897.....	83,110	379,166	622	8,214	1,773	106,396	1,621	94,398	170	145,184	117	11,088
1898.....	89,067	407,569	1,961	23,531	2,109	126,546	2,153	92,590	76	66,316	121	4,808
1899.....	85,570	359,486	1,127	14,496	1,904	106,618	2,061	81,553	88	85,908	75	6,266
1900.....	86,273	379,599	463	6,014	1,871	97,281	1,905	95,440	115	103,790	114	9,787

Year.	Nitric Acid.		Oxide. (Potash.)		Ozokerite.		Peat and Peat Coke.		Petroleum.			
									Crude.		Refined.	
1896.....	360	$28,808	4,164	$382,414	5,722	$766,681	2,701	$7,886	1,815	$20,734	23,106	$897,427
1897.....	310	20,909	5,997	381,395	5,158	762,570	1,655	4.533	1,600	15,364	13,062	513,700
1898.....	294	19,384	7,252	465,479	4,462	696,048	3,400	9,929	1,076	10,330	3,062	46,838
1899.....	420	27,313	10,113	760,568	5,441	859,600	4,010	11.710	1,823	21,873	7,778	147,784
1900.....	519	33,521	7,792	641,358	5,162	1,032,330	5,607	16,822	2,313	35,622	21,070	446,284

Year.	Potassium Salt Chloride.		Pyrites.		Quicksilver.		Salt.		Silica. (Quartz and Quartz Sand.)		Silver.	
											Bullion—Kg.	
1896.....	1,026	$28,734	341	$1,842	569	$423,634	11,811	$70,868	32,844	$98,727	2,360	$42,952
1897.....	1,005	36,166	955	1,379	529	408,697	182	1,091	31,347	94,727	4,120	66,250
1898.....	994	35,798	3,039	16,413	468	378,548	240	1,439	39,033	117,806	4,870	78,310
1899.....	974	35,078	5,911	29,123	490	456,690	117	705	68,412	210,142	48,940	849,084
1900.....	879	31.633	17,163	102,969	492	517,080	1,915	11,490	69,434	212,744	54,000	961,200

Year.	Silver.—*Continued.*						Slag and Slag Wool.		Slate, Roofing and Other.	
	Coin—Kg.		Old and Dross. Kg.		Ore.					
1896.....	182,950	$3,073,482	123,220	$76,952	16	$832	83,187	$266,200	4,602	$102,970
1897.....	114,560	1,681,500	116,700	68,648	(b)	.....	65,966	131,931	4,561	102,461
1898.....	36,130	572,376	121,400	71,280	1	56	75,018	180,043	4,972	110,892
1899.....	15,240	221,732	84,840	180,490	12	468	109,180	392,048	5,535	124,080
1900.....	17,441	271,729	97,800	25,000	69	4,397	125,113	450,405	5,205	116,551

Year.	Sodium.								Stone.	
	Carbonate.		Carbonate, Calcined.		Nitrate, Crude.		Salts, Potassium Nitrates, Refined.		Lithographic.	
1896.....	497	$5,134	2,487	$59,355	55	$2,906	160	$13,970	6	$225
1897.....	589	7,762	2,572	61,574	61	2,572	120	9,726	22	1,115
1898.....	852	13,140	2,465	61,624	33	1,344	140	12,951	8	405
1899.....	1,284	25,577	1,562	31,564	24	3,588	136	12,565	11	565
1900.....	1,236	22,067	548	14,250	35	1,546	117	7,939	7	351

Year.	Stone.—*Continued.*								Sulphur		Sulphuric Acid	
	Limestone.		Marble		Paving.		Not Elsewhere Specified.					
1896.....	[illegible]								1,231	$32,625	6,212	$78,940
1897.....									947	18,931	7,908	94,153
1898.....									933	17,454	9,280	97,911
1899.....									905	17,694	12,432	144,730
1900.....									1,205	25,694	12,698	149,705

Year.	Tin.						Whetstones.		Zinc.			
	Ingot and Bar.		Ore, Matte, Etc.		Ash.				Ash.		Metal.	
1896.....	130	[illegible]								$15,569	1,556	$95,671
1897.....										14,198	770	48,142
1898.....										16,677	1,114	75,452
1899.....										4,659	1,624	134,973
1900.....						2,444			180	3,546	1,098	87,982

Year.	Zinc.—*Continued.*						Metal Wares Other than Iron and Precious Metals.		Ores and Minerals Unspecified.	
	Ores.		Sheets, etc.		White.					
1896.....	9,453	$151,242	1,139	$126,195	1,825	$153,325	4,362	$2,944,000	45,848	$628,762
1897.....	12,914	247,950	998	106,232	1,673	140,532	4,486	3,180,800	47,653	680,364
1898.....	14,065	337,562	757	96,141	1,240	114,080	4,841	3,234,400	67,531	914,134
1899.....	20,461	613,818	1,313	211,468	1,096	100,823	5,250	4,078,400	82,865	1,081,906
1900.....	20,379	570,615	619	96,884	1,719	158,166	5,828	4,428,600	95,612	1,162,759

(*a*) From *Statistik des Auswärtigen Handels des Oesterreichisch Ungarischen Zollgebiets.* (*b*) Not reported.

MINERAL PRODUCTION OF BOSNIA AND HERZEGOVINA. (*a*) (METRIC TONS AND DOLLARS.)

Year.	Chrome Ore.		Copper.		Copper Ore.	Iron, Pig.		Iron Ore.	Lignite.		Manganese Ore.		Quicksilver.	Salt.	
1896	443	$5,426	206	(*b*)	(*b*)	10,120	$118,063	(*b*)	222,724	$187,870	6,621	$45,019	(*b*)	13,720	$384,157
1897	396	.....	135	.....	3,847	15,606	.....	37,095	229,643	.....	5,344	33,772	(*b*)	13,919	389,729
1898	458	.....	156	.....	3,760	15,263	.....	57,935	270,752	.....	5,320	.....	4·0	14,496	.....
1899	200	3,136	180	$57,000	3,980	13,730	181,465	67,030	303,000	260,010	5,270	35,800	3·3	15,030	465,190
1900	100	1,400	141	47,472	3,008	38,960	531,359	133,454	394,516	312,447	7,989	45,000	6·7	15,791	480,557

(*a*) From *Osterr. Zeits., für Berg-, Hütten und Salinenwesen*, except the figures for 1897 and 1898, which were furnished by the "Bosnisches Bureau des K. und K. gemeinsamen Ministeriums." Besides the substances specified in the table there was also produced: In 1897, fahlore, 40 tons; in 1898, 452 tons; in 1899, 620 tons. Iron pyrites, in 1898, 3,670 tons. (*b*) Not reported.

BELGIUM.

THE most important articles of mineral production in Belgium are coal, iron, lead, zinc, manganese ore and phosphate of lime. Developments in these industries are described specifically under the respective captions elsewhere in this volume. The official statistics of production, imports and exports are summarized in the following tables:

MINERAL PRODUCTION OF BELGIUM. (*a*) (IN METRIC TONS AND DOLLARS; 5 f.—$1.)

Year.	Iron Ore.		Lead Ore.		Manganese Ore.		Pyrites.		Zinc Ore.				Totals.
									Blende.		Calamine.		
1896.....	307,031	$283,564	70	$1,610	23,265	$69,004	2,560	$5,370	7,070	$71,280	4,560	$48,970	$479,780
1897.....	240,774	252,902	108	3,230	28,372	68,540	1,828	3,990	6,804	74,340	4,150	41,370	444,373
1898.....	217,370	211,644	133	4,301	16,440	42,300	147	177	7,850	98,262	4,125	51,250	407,934
1899.....	201,445	214,620	137	6,540	12,120	31,160	288	380	c9,460	171,080	3,730	40,220	433,780
1900.....	247,890	264,020	230	12,656	10,820	26,070	400	228	c8,715	111,260	3,000	43,430	414,234

PRODUCTION OF MINERAL FUEL IN BELGIUM.

Year.	Coal.							Coke.		
	Quantity. Metric Tons.	Value.		Profit.		Number of Workmen.	Average Annual Wages.	Ovens, Active.	Number of Workmen.	Consumption of Coal. Metric Tons
		Total.	Per Ton	Total.	Per Ton					
1896	21,252,370	$40,402,020	$1·90	$2,179,400	$0·102	119,246	$196	3,555	2,415	2,709,720
1897.....	21,492,446	44,134,420	2·05	3,911,350	·182	120,382	205	3,845	2,566	2,968,680
1898.....	22,068,335	48,578,780	2·20	4,654,921	·210	122,846	219	4,098	2,519	2,944,096
1899.....	22,072,068	54,888,780	2·49	7,568,600	·343	125,258	234	(*d*)	(*d*)	(*d*)
1900.....	23,462,817	81,693,960	3·48	12,453,600	·531	132,749	283	(*d*)	(*d*)	(*d*)

Year.	Coke—*Continued.*			Briquettes from Coal.					
	Quantity. Metric Tons.	Value.		Number of Works, Active.	Number of Workmen.	Consumption of Coal. Metric Tons.	Quantity. Metric Tons.	Value.	
		Total.	Per Ton					Total.	Per Ton
1896.....	2,004,430	$5,700,599	$2·84	36	1,334	1,092,340	1,213,760	$2,910,596	$2·40
1897.....	2,207,840	7,572,891	3·43	37	(*b*)	1,129,791	1,245,114	3,112,785	2·50
1898.....	2,161,162	8,104,357	3·75	37	1,191	1,227,720	1,351,894	3,692,049	2·68
1899.....	2,304,607	9,448,889	4·10	(*d*)	(*d*)	(*d*)	1,276,050	4,096,120	3·21
1900.....	2,434,678	13,098,567	5·38	40	(*d*)	(*d*)	1,395,910	6,574,736	4·71

METALLURGICAL PRODUCTION OF BELGIUM. (*a*) (IN METRIC TONS AND DOLLARS; 5 f. = $1.)

Year.	Iron, Crude.								
	Forge Pig.			Foundry Pig.			Bessemer Pig.		
	Quantity.	Value.		Quantity.	Value.		Quantity.	Value.	
		Total.	Per Ton		Total.	Per Ton		Total.	Per Ton
1896.....	362,451	$3,784,840	$10·30	84,275	$805,880	$9·56	193,518	$2,284,720	$11·81
1897.....	426,382	4,653,486	10·91	78,410	912,300	11·63	183,701	2,377,210	12·94
1898.....	308,875	3,329,775	10·78	93,645	1,000,720	10·69	173,085	2,243,380	12·96
1899.....	317,029	4,071,540	12·84	84,165	1,122,600	13·34	169,664	2,417,210	14·24
1900.....	305,344	4,839,754	15·85	88,335	1,480,280	16·75	176,557	3,381,420	19·15

Year.	Iron, Crude—*Continued.*						Iron, Manufactures of.			
	Thomas Pig.			Total Pig.			Bar, Crude.		Rails.	
	Quantity.	Value.		Quantity.	Value.					
		Total.	Per Ton		Total.	Per Ton				
1896.....	307,779	$3,336,580	$10·84	959,414	$10,316,180	$10·75	81,394	$2,030,500	1,027	$27,720
1897.....	333,958	4,001,380	11·98	1,095,087	12,144,076	11·73	106,606	2,801,200	1,448	40,400
1898.....	397,80:	4,898,140	12·31	979,755	11,580,970	11·82	123,993	3,216,770	837	23,350
1899.....	453,718	7,271,640	16·03	1,024,576	14,880,790	14 52	(*d*)	....	(*d*)	.....
1900.....	447,271	8,584,636	19·19	1,017,507	18,286,040	17·97	(*d*)	.....	(*d*)	.....

Year.	Iron, Manufactures of—*Continued.*						Lead, Crude.		Silver—Kg.	
	Sheet and Plate.		Wrought.		Other Manufactures.					
1896.....	112,597	$3,365,698	851	$50,240	298,163	$7,396,770	17,222	$1,029,980	28,509	$687,900
1897.....	100,252	3,148,800	872	47,800	263,644	6,834,000	17,028	1,101,760	30,073	681,422
1898.....	91,686	2,831,800	993	61,440	267,521	7,061,230	19,330	1,252,490	116,085	2,477,170
1899.....	(*d*)	.....	(*d*)	.....	(*d*)	.....	(*d*)	.....	(*d*)	.....
1900.....	73,572	3,154,126	(*d*)	.....	284,591	10,846,042	16,365	1,395,600	145,695	3,084,400

Year.	Steel.									
	Ingots, Cast and Blooms.		Rails.		Tires.		Sheet.		Forge.	
1896.....	598,974	$10,102,490	147,183	$3,174,780	10,497	$367,670	268,009	$6,070,020	6,702	$204,910
1897.....	616,541	11,104,800	136,911	3,295,800	10,870	427,200	272,539	6,743,400	23,104	586,400
1898.....	653,523	11,877,040	117,751	2,868,960	10,958	408,920	314,150	7,981,610	17,902	516,700
1899.....	(*d*)	.....	(*d*)	.....	(*d*)	.....	(*d*)	.....	(*d*)	.....
1900.....	(*d*)	.....	(*d*)	.....	(*d*)	.....	(*d*)	.....	(*d*)	.....

Year.	Steel—*Continued.*						Zinc.			
	Plates.		Wire.		Total.		Crude.		Sheet.	
1896.....	64,653	$2,216,640	22,267	$591,820	519,311	$12,625,840	118,361	$9,182,440	36,238	$3,244,610
1897.....	64,366	2,354,000	19,567	558,400	527,617	13,965,600	116,067	9,936,090	37,011	3,450,710
1898.....	87,219	2,978,590	19,753	567,620	567,726	15,322,000	119,671	11,881,660	35,587	3,841,190
1899.....	(*d*)	.....	(*d*)	.....	633,950	19,230,860	122,843	14,925,770	34,289	4,616,950
1900.....	(*d*)	.....	(*d*)	.....	568,539	20,984,944	119,317	11,926,280	38,825	4,543,800

QUARRY PRODUCTION OF BELGIUM. (*a*) (VALUES IN DOLLARS; 5 f. = $1.)

Year.	Barytes. Metric Tons.		Chalk, Marl. Cubic Meters.		Clay. Metric Tons.		Feldspar. Cubic Meters.		Flint for Earthenware. Cubic Meters		Flint and Gravel for Ballast. Cubic Meters.		Mineral Paints. Ochers. Cu. Met.	
1896....	25,000	$35,000	191,100	$66,400	83,020	$84,500	2,000	$3,200	23,450	$19,160	244,050	$123,140	700	$2,800
1897....	23,000	32,200	204,600	90,680	270,715	359,952	1,100	1,940	23,050	17,720	235,495	110,819	350	1,450
1898....	21,700	30,380	287,805	136,220	287,805	416,240	1,000	1,980	22,150	17,700	360,960	177,700	290	1,180
1899....	25,900	36,260	351,800	115,540	291,125	398,968	1,525	3,350	25,185	20,690	258,835	121,338	300	1,200
1900....	38,800	55,100	377,550	88,980	313,205	435,540	1,960	3,100	25,700	21,440	263,850	124,798	300	1,200

Year.	Phosphate of Lime. Cubic Meters.		Sand. Cubic Meters.		Slate. Pieces.	Slate. Cubic Meters	Slate. Total Value.	Building Stone—Cubic Meters. Conglomerate.		Dolomite.		Flagstones. Square Meters.	
1896...	297,470	$537,320	418,720	$162,960	35,980,000	1,150	$269,500	160	$4,000	21,500	$7,200	131.400	$91,720
1897...	350,056	436,762	559,141	237,196	41,422,000	1,445	335,780	280	5,500	52,780	13,908	107,572	71,646
1898...	156,920	303,230	287,805	136,220	42,311,000	210	350,660	180	4,680	37,100	13,068	170,672	157,650
1899...	190,090	342,180	627,770	241,696	44,167,000	200	358,112	200	5,400	56,400	19,688	144,280	127,355
1900...	215,670	367,164	653,780	250,996	43,941,000	1,410	333,210	380	7,900	45,000	18,050	153,217	142,343

Year.	Stone. Freestone.		Limestone.		Limestone for Flux. Cubic Meters.		Marble. Cubic Meters.		Paving Stones. *Pieces.*		Whetstones and Hones—*Pieces.*	
1896	152,420	$2,742,300	2,646,305	$2,143,500	164,900	$75,360	16,315	$544,680	102,295,950	$1,793,720	45,950	$6,680
1897	181,746	3,076,924	3,010,877	2,730,730	225,300	89,085	17,797	471,954	95,542,700	1,730,875	43,150	16,740
1898	215,417	3,177,534	2,968,997	2,580,695	212,685	74,740	16,610	547,100	108,025,000	2,016,314	89,150	22,590
1899	189,294	3,249,146	3,238,875	2,735,025	195,505	77,956	17,740	601,170	114,103,900	2,236,411	82,100	14,160
1900	157,294	3,200,248	3,228,205	3,020,602	229,250	89,112	15,990	536,140	107,294,600	2,192,352	105,000	15,160

(a) From *Statistiques des Mines, Minières, Carrières, et Usines Métallurgiques*, by Emil Harzé. Belgium also produced, in 1896, manganese pig-iron, 11,391 tons, $154,160; kaolin, 190,960 cu. m., $213,560; and in 1897, manganese pig-iron, 12,636 tons, $199,700. (b) Not stated in the report. (c) Includes output of calamine. (d) Statistics not yet available.

MINERAL IMPORTS OF BELGIUM. (a) (IN METRIC TONS AND DOLLARS; 5 f. = $1.)

Year.	Ashes.		Cement.		Chemical Products. Soda Salts.		Chemical Products. Not Specified.	Clay Products. (b) Terra Cotta.		Clay Products. (b) Common Pottery.	
1896.....	6,747	$26,988	30,565	$188,392	194,202	$11,989,011	$5,436,285	85,486	$629,221	2,065	$103,231
1897.....	10,870	43,481	17,681	113,160	181,676	7,419,315	6,048,428	86,498	549,631	2,115	105,756
1898.....	8,199	32,796	34,039	231,471	152,164	5,083,089	6,896,420	92,149	610,058	2,007	104,436
1899.....	15,818	63,271	18,649	128,675	249,756	7,996,717	6,431,947	99,156	633,955	2,856	102,098
1900.....	15,428	61,711	12,778	86,856	232,941	7,332,966	7,157,219	90,852	585,216	4,281	127,254

Year.	Clay Products—*Con.* Earthenware.	Clay Products—*Con.* Porcelain	Coal.		Coal Briquettes.		Coke.		Copper and Nickel. Crude.	
1896.....	c$272,894	d$177,207	1,693,376	$5,249,466	1,561	$5,151	260,273	976,094	15,506	$3,597,466
1897.....	c298,535	d188,434	2,017,344	6,455,501	632	2,212	269,606	1,159,306	14,821	3,556,943
1898.....	179,866	345,067	2,202,517	7,268,306	1,756	6,585	180,590	784,590	14,947	5,083,274
1899.....	438,072	233,394	2,844,274	10,523,814	10,722	42,960	296,508	1,482,540	8,227	3,330,798
1900.....	450,685	263,241	3,288,510	13,976,167	21,813	121,062	289,673	1,767,005	13,768	5,507,109

Year.	Copper and Nickel.—*Con.* Hammered, Drawn or Rolled.		Copper and Nickel.—*Con.* Wrought.	Glass and Glassware. Common (Bottles, Broken Glass, etc.)		Glass and Glassware. All Other Kinds.	Gold (Including Platinum). Ore—Kg.		Gold (Including Platinum). Unwrought—Kg.	
1896.....	1,109	$321,718	$188,931	6,980	$213,380	$541,225	93	$614	4,923	$3,390,962
1897.....	1,418	405,576	193,242	4,699	143,130	664,176	.....	.....	3,824	2,633,971
1898.....	1,821	765,000	205,705	4,247	99,608	635,021	8,390	55,374	1,282	883,041
1899.....	2,174	999,985	226,853	3,757	90,473	651,206	51	337	1,186	782,477
1900.....	2,087	960,164	251,765	5,671	134,352	663,386	1,250	8,250	1,728	1,190,946

Year.	Gold.—*Continued.* Coin.	Gold.—*Continued.* Jewelry, etc.	Guano.		Iron and Steel Filings.		Iron. Ore.		Iron. Pig.	
1896.....	599,540	$757,507	25,946	$1,037,846	11·1	93	2,069,676	$3,982,385	394,899	$3,897,069
1897.....	1,726,700	701,535	5,162	185,825	26·4	227	2,544,377	4,884,316	392,198	3,815,918
1898.....	372,000	840,593	10,657	383,664	18·0	158	2,252,553	4,279,850	317,899	3,782,157
1899.....	744,000	965,170	16,111	579,991	184·0	1,748	2,621,152	5,242,304	362,458	5,665,168
1900.....	459,420	921,694	15,832	569,964	3·0	30	2,528,615	5,310,092	309,674	5,521,417

Year.	Iron.—*Continued.*						Lead.				Lime.	
	Old.		Hammered, Drawn or Rolled.		Wrought.		Pig.		Manufactures.			
1896.....	53,802	$688,668	22,812	$646,150	6,118	$469,031	35,221	$1,987,173	$17,231		11,522	$22,699
1897.....	51,965	670,603	26,054	792,873	6,336	491,296	43,840	2,630,429	91,580		13,184	26,236
1898.....	52,296	690,320	25,470	761,167	14,918	879,347	54,867	3,489,549	50,728		12,674	25,349
1899.....	61,510	922,647	34,960	1,127,656	6,934	559,899	60,649	4,184,756	191,508		13,811	28,184
1900.....	62,053	992,841	32,783	1,138,576	7,983	726,074	58,141	4,767,579	148,040		11,448	25,757

Year.	Petroleum.				Resins and Bitumens, Not Specified.		Salt.			
	Crude.		Refined.				Crude.		Refined.	
1896.....	95	$1,336	158,979	$5,405,275	216,278	$10,813,891	92,408	$554,449	38,785	$387,852
1897.....	988	13,831	149,501	4,843,844	237,570	11,878,487	96,805	580,827	39,193	391,926
1898.....	332	7,446	161,281	5,419,070	269,914	13,495,710	92,300	553,804	50,136	501,364
1899.....	2,479	49,590	166,404	5,990,562	264,718	13,235,897	81,324	487,945	50,647	506,475
1900.....	1,751	36,773	158,064	5,848,381	253,788	12,689,402	97,812	586,871	59,875	598,748

Year.	Silver.						Steel.					
	Ore—Kg.		Bullion—Kg.		Coin.	Jewelry, etc.	Ingot.		Bars, Sheets, and Wire.		Wrought.	
1896.....	1,476,582	$177,190	8,980	$223,480	$6,461,840	$415,967	28,435	$561,744	15,263	$479,341	986	$233,924
1897.....	2,533,237	253,324	487,851	9,357,020	*c* 2,083,040	460,244	25,370	518,371	25,869	634,766	1,147	286,415
1898.....	461,914	46,191	299,869	5,987,990	7,655,200	449,244	25,142	526,442	24,761	805,918	1,013	256,925
1899.....	2,522,950	252,295	105,723	2,114,460	14,272,080	520,070	11,666	256,737	33,552	1,088,468	1,070	275,521
1900.....	921,500	92,150	11,366	234,140	7,324,560	513,767	19,705	486,587	42,580	1,594,780	1,295	336,038

Year.	Stone.								Sulphur.	
	Roofing Slate. *1,000 Pieces.*		Building Stone, Including Marble and Alabaster.		Cut, Polished, etc.		Paving.	All Other Kinds.		
1896.....	38,209	$152,834	40,511	$891,237	$61,769	6,163	$22,187	81,360 $394,964	14,399	$403,177
1897.....	38,754	162,765	47,929	1,054,432	111,313	13,197	47,509	182,950 1,097,417	13,261	371,307
1898.....	38,216	198,724	45,544	1,093,052	63,665	8,926	37,489	239,281 1,312,764	13,322	373,037
1899.....	35,888	186,616	49,498	1,484,940	83,372	7,835	37,608	216,231 1,406,392	8,449	236,567
1900.....	34,331	216,284	60,057	1,801,698	145,736	3,761	18,053	135,245 1,622,934	17,516	525,482

Year.	Tin.			Tin Plate.			Zinc.			Ores, Crude Not Elsewhere Specified.
	Ingot.		Manufactures.	Unwrought.		Wrought.	Ingot.		Manufactures.	
1896.....	4,617	$1,662,044	$2,845	3,208	$243,408	$27,425	20,182	$1,614,588	$11,230	$10,227,349
1897.....	1,609	547,118	2,634	3,875	294,533	22,972	16,320	1,387,218	10,661	13,048,392
1898.....	1,208	628,084	2,545	3,848	256,180	29,900	17,441	1,757,108	11,575	13,497,359
1899.....	1,113	667,504	4,373	3,900	306,564	46,437	11,058	1,150,063	11,486	17,728,858
1900.....	1,653	1,090,720	5,540	5,036	433,060	50,829	11,478	1,147,817	12,054	15,451,733

(*a*) From *Statistique de la Belgique; Tableau General du Commerce avec les Pays, Etrangers, Brussels.* (*b*) There was imported in 1897 also slabs of pottery for paving, building, etc., 7,755 metric tons, $172,795. (*c*) Corresponding in 1896 to 3,668 metric tons, and in 1897 to 3,718 metric tons. (*d*) Corresponding in 1896 to 894 metric tons, and in 1897 to 815 metric tons. (*e*) Corresponding to 52,076 kg.

MINERAL EXPORTS OF BELGIUM. (*a*) (IN METRIC TONS AND DOLLARS; 5 f. = $1.)

Year.	Ashes.		Cement.		Chemical Products.			Clay Products.			
					Soda Salts.		Not Specified.	Terra Cotta. *No. of Pieces.*		Common Pottery.	
1896.....	1,084	$4,338	277,615	$1,665,690	42,857	$2,298,603	$6,819,396	302,526	$1,913,054	2,628	$131,394
1897.....	2,675	10,701	322,024	2,060,951	59,054	2,202,874	7,236,116	294,815	1,773,837	3,197	159,867
1898.....	615	2,459	419,132	2,850,092	106,252	2,718,179	7,300,805	247,970	1,497,938	3,186	81,066
1899.....	400	1,598	415,602	3,074,655	109,253	2,790,617	6,431,947	328,733	1,974,565	3,216	96,153
1900.....	2,148	8,590	408,284	2,776,131	75,492	2,272,301	6,592,217	289,759	1,742,812	5,915	127,254

Year.	Clay Products.—*Continued.*				Coal.		Coal Briquettes.		Coke.	
	Earthenware.		Porcelain.							
1896.....	4,692	$513,950	586	$54,332	4,649,799	$14,414,377	459,974	$1,517,914	863,067	$3,236,501
1897.....	4,905	534,532	264	45,395	4,448,544	14,226,341	615,074	2,152,759	909,486	3,910,789
1898.....	10,981	640,025	218	35,372	4,579,255	15,113,851	666,265	2,498,493	878,435	3,865,114
1899.....	4,417	488,133	264	39,759	4,568,988	16,905,071	525,625	2,155,062	1,008,740	5,043,700
1900.....	5,010	525,671	261	37,248	5,260,991	22,359,312	604,864	3,356,995	1,073,813	6,547,209

Year.	Copper and Nickel.					Glass and Glassware.				
	Crude.		Hammered, Drawn or Rolled.		Wrought.	Common (Bottles, Broken Glass, etc.).		Plate.	All Other Kinds.	
1896.....	11,700	$2,714,477	2,078	$601,277	$168,594	3,647	$26,574	$3,468,668	178,611	$12,194,434
1897.....	9,994	2,398,659	1,996	570,761	198,665	3,546	26,468	3,761,219	174,229	11,448,859
1898.....	8,511	2,093,856	1,770	743,802	161,726	2,747	37,480	3,007,865	25,226	3,088,385
1899.....	4,665	1,866,089	2,111	970,882	261,060	3,850	88,283	4,942,296	196,842	12,553,516
1900.....	8,411	3,364,241	2,097	964,639	276,613	3,998	78,004	4,412,937	159,557	10,896,039

Year.	Gold (Including Platinum).				Guano.		Iron and Steel Filings.		Iron.	
	Unwrought—Kg.		Coin.	Jewelry, etc.					Ore.	
1896.....	3,713	2,557,514	$2,666,690	$75,570	14,633	$585,808	7,095	$59,007	389,285	$739,546
1897.....	2,547	1,754,374	605,120	126,385	14,044	505,585	534	4,595	410,817	780,552
1898.....	1,281	817,213	578,120	118,897	21,626	778,542	407	3,561	384,047	729,688
1899.....	504	347,758	998,200	118,916	18,213	655,669	289	2,270	318,415	636,830
1900.....	549	378,151	613,180	161,155	14,204	511,339	121	1,210	420,179	882,376

Year.	Iron.—*Continued.*								Lead.	
	Pig.		Old.		Hammered, Drawn or Rolled.		Manufactures.		Pig.	
1896.....	88,465	$1,192,480	18,416	$235,725	343,072	$9,072,611	44,952	$3,497,287	31,866	$1,725,144
1897.....	42,554	1,895,352	17,590	226,911	356,895	10,097,254	43,114	3,399,400	35,988	2,159,298
1898.....	16,789	223,453	23,326	309,676	234,562	4,155,448	51,520	4,151,200	40,302	2,563,246
1899.....	43,304	1,418,941	32,504	487,557	395,878	10,955,330	59,054	4,879,020	41,618	2,871,642
1900.....	35,313	1,317,952	43,736	699,778	270,524	9,158,530	65,279	6,122,112	46,566	3,818,425

Year.	Lead.—*Con.*	Lime.		Petroleum.				Resins and Bitumens, not Specified.	
	Wrought.			Crude.		Refined.			
1896.....	$36,821	477,218	$940,110	2	$23	29,321	$996,913	86,906	$4,345,315
1897.....	33,286	520,588	1,035,969	1	15	18,088	586,067	92,591	4,629,538
1898.....	16,450	546,199	1,092,399	782	13,256	19,556	657,067	107,806	5,390,353
1899.....	37,022	587,357	1,182,186	2,146	42,924	25,970	984,937	112,392	5,619,622
1900.....	8,952	617,666	1,389,749	1,759	36,938	21,812	807,036	97,970	4,898,475

Year.	Salt.				Silver.							
	Crude.		Refined.		Ore—Kg.		Bullion—Kg.		Coin—Kg.		Jewelry, etc.	
1896.....	1,434	$8,604	129	$1,287	19,400	$2,328	40,118	$1,043,068	16,696	$667,840	$137,137	
1897.....	498	2,959	231	2,309	423,160	42,316	57,993	1,158,660	521	20,851,320	189,959	
1898.....	298	1,789	386	3,864	595	59	107,385	2,125,700	327	13,083,640	127,194	
1899.....	506	3,037	885	8,850	116	12	54,358	1,087,160	337,079	13,483,160	214,175	
1900.....	2,345	14,070	799	7,989	.....	.....	38,331	789,619	32,621	1,304,840	103,121	

Year.	Steel.						Stone.					
	Ingot.		Bars, Sheets and Wire.		Manufactures.		Roofing Slate. *1,000 Pieces.*		Building Stone, Including Marble and Alabaster.		Cut, Polished, etc.	
1896.....	1,145	$23,272	179,878	$4,597,877	88,806	$7,843,777	15,485	$111,180	161,298	$1,290,387	$932,147	
1897.....	1,201	22,302	183,386	4,842,221	87,353	7,764,848	17,304	138,428	187,180	1,591,033	934,286	
1898.....	1,018	19,397	175,249	4,856,964	33,652	6,464,909	16,948	152,534	178,949	1,742,491	869,015	
1899.....	1,259	26,036	155,815	4,603,643	31,194	6,151,759	15,316	137,843	164,953	2,144,381	948,0[illegible]	
1900.....	974	22,793	146,121	4,854,049	28,877	5,170,862	12,836	100,118	171,126	2,224,636	872,381	

Year.	Stone.—*Continued.*				Sulphur.		Tin.		
	Paving.		All Other Kinds.				Ingot.		Manufactures.
1896.....	154,737	$1,197,335	796,331	$3,184,926	5,335	$149,371	1,055	$379,732	$873
1897.....	158,504	1,389,421	773,531	3,248,832	6,041	169,157	347	118,089	889
1898.....	159,455	1,449,530	917,654	4,221,212	6,355	177,960	508	263,982	2,394
1899.....	150,993	22,793	834,528	4,172,641	6,709	189,533	659	395,479	1,511
1900.....	178,057	1,709,351	1,022,780	5,113,904	7,363	220,880	495	326,479	2,903

Year.	Tin Plate.			Zinc.			Ores Not Specified.
	Unwrought.		Wrought.	Ingot.		Manufactures.	
1896.....	3,952	$309,625	$11,750	100,369	$8,029,501	$56,349	$4,236,708
1897.....	1,191	90,545	15,216	100,228	8,519,380	90,749	6,216,589
1898.....	973	74,903	10,562	108,507	10,807,318	102,583	7,080,013
1899.....	1,436	112,831	19,566	101,344	10,529,376	109,769	5,730,528
1900.....	941	80,889	10,221	99,233	9,923,302	98,302	6,690,189

(a) From *Statistique de la Belgique: Tableau General du Commerce avec les Pays Etrangers.*

CANADA.

THE mineral statistics of the Dominion of Canada as collected by the Geological Survey and the Bureaus of Mines of the various provinces, are summarized in the following tables:

MINERAL PRODUCTION OF THE DOMINION OF CANADA. (*a*) (IN METRIC TONS AND DOLLARS.)

Year.	Arsenic.		Asbestos and Asbestic.		Barytes.		Cement—*Barrels.* Natural Rock.		Cement—*Barrels.* Portland.		Chromite.	
1897....	*Nil.*	.....	27,617	$445,868	518	$3,000	85,450	$65,893	119,763	$209,380	2,302	$32,474
1898....	*Nil.*	.....	21,577	486,227	971	5,258	87,125	73,412	163,084	324,168	1,833	24,252
1899....	52	$4,872	22,988	483,299	653	4,402	131,397	119,508	255,366	513,963	1,796	23,760
1900....	275	22,725	27,797	763,431	1,207	7,575	123,428	99,994	283,124	545,596	2,118	27,000
1901....	631	41,676	34,556	1,186,434	522	3,842	133,328	94,415	297,066	535,615	1,596	25,444

Year.	Clay. Fire Clay.		Clay. Pottery	Clay. Terra-Cotta.	Clay. Tile and Sewer Pipe. (*d*)	Coal.		Coke. (*e*)		Copper (In Ore, etc.). (*f*)	
1897....	1,921	$5,759	$129,629	$155,595	$389,250	3,434,756	$7,303,597	55,044	$176,457	6,083	$1,501,660
1898....	*b*1,969	5,000	135,000	167,902	166,421	3,785,408	8,227,958	65,721	219,200	8,146	2,159,556
1899....	543	1,295	200,000	220,258	161,546	4,142,242	9,040,058	91,468	350,022	6,840	2,655,319
1900....	1,129	4,130	200,000	259,450	231,525	4,837,337	12,668,475	142,555	649,140	8,582	3,063,119
1901....	*b*1,200	4,300	200,000	278,671	250,115	5,613,689	14,671,122	339,043	1,264,360	18,561	6,600,104

Year.	Feldspar.		Gold—Kg. (*h*)		Graphite.		Grindstones.		Gypsum.		Iron Ore.	
1897....	1,270	$3,290	9,380	$5,027,016	396	$16,240	4,148	$42,340	217,392	$944,531	50,000	$130,990
1898....	2,268	6,250	20,613	13,700,000	(*g*)	11,098	(*g*)	39,465	198,908	220,440	52,763	152,510
1899....	2,722	6,000	31,673	21,049,730	1,105	16,179	4,092	43,265	221,869	257,329	69,997	248,372
1900....	(*g*)	.....	42,008	27,916,752	1,744	30,940	5,034	53,450	228,614	259,009	*j* 32,103	583,158
1901....	4,742	4,710	36,808	24,462,222	1,307	28,880	5,173	55,690	266,605	340,148	75,408	1,212,113

Year.	Lead (In Ore, etc.). (*k*)		Lime—*Bushels.*		Manganese Ore.		Mica.	Mineral Paints. (Ochers.)		Mineral Waters.
1897....	17,698	$1,396,853	(*g*)	$650,000	14	$1,166	$76,000	3,542	$33,560	(*g*)
1898....	14,477	1,206,399	(*g*)	.....	45	1,600	117,598	2,124	18,600	$155,000
1899....	9,917	977,250	(*g*)	.....	279	3,960	163,000	3,555	19,900	100,000
1900....	28,654	2,760,521	(*g*)	.....	(*g*)	.....	166,000	1,783	15,398	75,000
1901....	23,029	2,199,784	(*g*)	.....	399	4,820	160,000	2,026	16,735	100,000

Year.	Natural Gas.	Nickel (In Ore, etc.). Kg.		Petroleum, Crude. *Barrels.* (*m*)		Phosphate (Apatite).		Platinum.	Pyrites.	
1897	$325,873	1,813,321	$1,399,176	709,857	$1,011,546	824	$3,984	$1,600	35,299	$116,730
1898.....	320,000	2,502,808	1,820,838	700,790	981,106	665	3,665	(*g*)	29,226	128,872
1899.....	387,271	2,605,461	*r*2,067,840	808,570	1,202,020	2,722	18,000	835	25,117	110,748
1900.....	417,094	3,212,497	*r*3,327,707	710,498	1,151,007	1,284	7,106	(*g*)	36,316	155,164
1901.....	312,359	3,686,619	*r*4,594,523	588,528	953,415	(*g*)	.....	(*g*)	25,645	113,044

Year.	Sand and Gravel (Exports).		Sand. (Moulding.)		Salt.		Silver (In Ore, etc.)—Kg. (n)		Slate.	Soapstone.	
1897.....	118,768	$76,739	4,976	$10,931	46,583	$225,730	172,891	$3,323,395	$42,800	142	$350
1898.....	(q)	.....	9,591	21,098	51,839	248,639	137,911	2,583,298	40,791	(q)	.....
1899.....	(q)	.....	12,450	27,490	51,796	234,520	95,762	1,884,371	33,406	408	1,960
1900.....	(q)	.....	(q)	.....	56,296	279,458	188,801	2,730,598	12,100	881	1,365
1901.....	179,040	117,465	13,267	29,240	58,927	262,398	158,698	2,998,668	9,980	235	842

Year.	Stone.								Various Products. (p)
	Brick, Stone, etc.	Flagstones. Sq. Ft.		Granite.		Limestone for Flux.		Marble.	
1897.....	b $1,000,000	(q)	$7,190	9,385	$61,934	27,371	$30,258	(q)	$336,197
1898.....	c3,600,000	(q)	4,250	(q)	73,573	30,766	31,153	(q)	491,660
1899.....	4,250,000	(q)	7,600	(q)	90,542	48,265	45,662	(q)	487,271
1900.....	4,850,000	(q)	5,250	(q)	80,000	48,050	39,333	(q)	.....
1901.....	4,820,000	(q)	.....	(q)	155,000	153,719	183,162	(q)	303,126

(a) From *Reports Compiled by the Geological Survey of Canada.* (b) Estimated. (c) Includes brick, building stone, lime, sands, gravels, tiles, etc. (d) Value of tile in 1897, $225,000; sewer pipe, $164,250. In 1898 and 1899 sewer pipe is alone reported. (e) Oven coke, all the production of Nova Scotia and British Columbia. (f) Copper contents of ore, matte, etc., at the following values per lb.: 1897, 11$\frac{1}{16}$c.; 1898, 12$\frac{1}{16}$c.; 1899, 17·61c.; in 1900, 16·19c. (h) Fine kilograms calculated at $664·60 per kg. (i) Export returns. (j) Amount of pig iron produced from native ore; the total amount of pig iron smelted was 96,575 short tons, valued at $1,501,696. (k) Lead contents of ores, etc., at the following values per lb.: 1897, 3·6c.; 1898, 3·78c.; 1899, 4·47c.; 1900, 4·37c.; 1901, 4·34c. (m) Calculated from inspection returns at 100 gals. crude to 42 gals. refined. The value of the crude per bbl. of 35 imp. gals. was, in 1897, $1·42; in 1898, $1·40; in 1899, $1·48½, and in 1900 and 1901 when the ratio was 100 gal. to 54 refined, $1.62 per bbl. (n) Silver contents of ores, values for production and exports per oz.: 1897, $0·598; 1898, $0·583; 1899, $0·5958; 1900, $0·6141; in 1901, $0·5895. (p) In 1897, includes mercury, 312 kg. ($324), also sundry minerals, estimated in part and including actinolite and tripolite; in 1898, includes tripolite, 922 metric tons ($16,660); in 1900, tripolite, 805 metric tons, $1,950; in 1901 sundry minerals estimated in part and including actinolite, 482 metric tons, $3,126. (q) Not reported. (r) Nickel contents of ore, matte, etc., in 1899, at 36c. per lb.; in 1900 at 47c. per lb.; in 1901 at 50c. per lb.

MINERAL IMPORTS OF THE DOMINION OF CANADA. (a) (IN METRIC TONS AND DOLLARS.)

Year. (h)	Aluminum.		Asphalt.		Brass. (f)	Buhrstones. Number.		Cement.	Chalk.	Chloride of Lime.		Cryolite.	
1897..	g8	$5,717	342	$9,013	$457,342	1,499	$1,827	$260,842	$11,826	1,861	$49,368	16	$2,106
1898..	(i)	7,102	6,006	55,164	560,014	899	1,813	376,315	14,362	1,765	55,987	17	2,315
1899..	(i)	9,275	8,196	95,800	747,557	1,116	1,759	480,414	14,544	1,857	50,801	50	2,120
1900..	(i)	12,543	2,825	68,748	853,599	1,250	1,546	520,593	12,212	1,967	65,224	18	2,721
1901..	(i)	16,202	2,849	67,587	985,776	3,641	5,762	675,768	16,690	1,605	54,136	20	2,158

Year. (h)	Clay Products.			Coal.				Coal Tar. Barrels.		Coke.	
	Bricks and Tiles.	Clays.	Earthenware & China.	Anthracite. (b)		Bituminous. (b)					
1897..	$165,073	$59,386	$595,822	1,322,049	$5,695,168	1,595,789	$3,313,826	23,661	$36,942	75,596	$267,540
1898..	168,012	72,795	674,874	1,325,139	5,847,685	1,735,838	3,225,151	26,702	35,194	122,527	347,040
1899..	255,237	88,517	916,727	1,583,471	6,490,509	2,220,725	3,736,663	39,206	54,447	128,172	362,826
1900..	499,128	122,965	960,254	1,500,863	6,602,912	2,512,871	4,409,313	50,484	73,874	170,471	506,839
1901..	551,746	141,251	1,139,058	1,933,283	7,923,950	3,097,691	5,556,253	54,928	88,093	308,786	680,138

Year. (h)	Copper. (f)	Copper Sulphate.		Emery (Wheels and Ground).	Explosives.	Flint and Stones.		Fuller's Earth.	Glass.	Gold and Silver.	
										Coin and Bullion.	Manufactures.
1897..	$270,086	516	$40,469	$11,231	$131,562	475	$5,244	$1,552	$1,139,764	$4,676,094	$296,143
1898..	667,452	738	57,497	15,478	141,731	389	5,344	3,330	1,024,706	4,390,844	297,242
1899..	798,326	726	61,749	22,343	212,968	243	2,977	3,418	1,343,058	4,705,134	342,320
1900..	1,271,270	752	87,847	44,882	247,511	280	4,342	2,661	1,658,691	8,297,438	339,145
1901..	1,142,771	673	73,190	39,116	306,067	250	3,626	3,147	1,584,922	3,537,294	367,857

Year. (h)	Gravel and Sand.		Iron and Steel. (f)		Kainite.		Lead. (f)	Lead Pigments and Zinc White.		Lime. *No. of Bbls.*		Litharge.	
1897..	19,330	$25,222	$11,326,484	206	$5,984	$233,125	4,677	$347,539		16,108	10,539	546	$34,538
1898..	29,164	43,287	16,407,644	49	1,008	335,278	5,753	448,659		12,850	9,002	519	32,904
1899..	27,477	42,209	19,768,725	30	777	308,450	6,581	514,849		15,720	11,194	492	32,518
1900..	32,509	41,280	27,423,910	143	2,339	322,446	6,054	634,492		12,865	11,211	415	29,176
1901..	35,744	42,891	25,062,404	88	1,261	312,570	4,677	462,353		19,657	14,584	557	37,944

Year. (h)	Litho-graphic Stones.	Mineral Oils. *Gallons.*		Mineral Paints. (Ocher.)		Ores of Metals.		Phos-phorus.		Potassium Salts.			
										Except Saltpeter.		Saltpeter.	
1897..	$6,360	7,696,358	$614,932	298	$5,533	22,021	$105,072	16	$8,575	265	$35,182	456	$43,066
1898..	7,791	8,175,006	623,364	448	9,428	69,766	155,583	5	4,618	244	33,502	627	51,236
1899..	6,223	9,708,189	682,447	502	10,432	61,254	153,959	1	778	472	52,177	980	65,186
1900..	6,294	8,623,094	739,266	486	10,050	61,580	282,191	1	852	733	64,538	602	52,225
1901..	9,584	10,667,755	872,696	365	7,849	92,764	598,016	5	3,438	476	59,786	581	46,804

Year. (h)	Precious Stones and Jewelry.	Pumice Stone.	Quicksilver.		Sal Ammonia.		Salt.		Silex.		Slate.
1897.....	$506,728	$2,908	34	$33,584	69	$7,258	108,809	$345,587	116	$3,415	$21,615
1898.....	743,607	3,829	27	26,425	38	3,721	96,935	326,202	141	2,773	24,907
1899.....	933,837	5,973	47	51,695	53	5,062	88,373	300,859	180	2,595	33,100
1900.....	732,675	5,604	39	51,987	60	6,987	92,797	325,433	182	2,876	53,707
1901.....	1,279,617	5,516	64	94,564	76	9,459	98,127	339,887	178	2,106	72,164

Year. (h)	Sodium Salts, Except Chloride.		Stone and Marble. (f)	Sulphur.		Tin. (f)	Whiting.	Zinc. (f)
1897.....	13,988	$375,651	$173,822	3,932	$87,712	$1,272,600	22,541	$96,708
1898.....	16,026	446,799	189,386	17,248	373,786	1,548,346	25,761	136,849
1899.....	20,742	476,706	237,543	11,121	265,799	1,370,239	34,310	154,440
1900.....	16,748	453,783	250,034	9,584	215,433	2,415,696	34,575	167,642
1901.....	18,631	509,278	255,550	10,827	270,608	2,334,668	60,878	173,899

MINERAL EXPORTS OF DOMESTIC PRODUCTS FROM THE DOMINION OF CANADA. (a) (IN METRIC TONS AND DOLLARS.)

Year. (h)	Antimony Ore.		Asbestos.		Barytes	Clay Products.			Cement.	Cinders.	Coal.		Coin and Bullion.
						Brick. *Thousands.*		Clay, M'f's of.					
1897..	(i)	.....	9,951	$510,916	(i)	906	$5,236	$796	$1,332	$922	999,789	$3,330,017	$927,298
1898..	1,118	$15,295	16,714	510,368	(i)	276	1,553	343	609	(i)	981,696	3,273,415	1,045,923
1899..	(i)	.....	13,172	453,176	(i)	93	707	339	2,789	50	1,034,963	3,562,794	1,101,245
1900..	6	200	16,478	490,909	(i)	342	2,314	215	2,274	66	1,581,422	4,771,441	1,670,068
1901..	219	5,074	26,715	864,573	3,820	798	5,807	761	3,554	10	1,888,588	5,307,060	1,978,489

Year. (h)	Coke.		Copper. (c)		Explo-sives.	Fertil-izers.	Glass and Glass-ware.	Graphite.		Grind-stones	Gypsum.		Iron and Steel, M'f's of
											Crude.	Ground	
1897..	1,692	$8,802	2,933	$540,439	93	$76,578	$36,584	$7,208	78	$3,584	$15,760	163,785	$183,876	$18,710	$522,966
1898..	3,275	7,341	4,203	832,546	92	74,305	46,864	7,494	348	6,428	18,785	163,612	193,515	2,587	606,089
1899..	4,024	15,684	3,812	917,420	151	115,065	51,224	11,788	663	12,749	18,619	148,525	166,922	7,611	706,411
1900..	12,558	33,770	6,272	1,387,213	212	155,764	51,410	11,016	1,742	30,054	22,196	211,734	236,034	2,622	1,425,113
1901..	60,129	192,910	11,938	2,655,467	434	240,535	37,706	13,574	2,746	40,099	38,304	172,010	185,208	25 472	1,432,961

Year. (h)	Lime.	M'f'es of Metals Not Iron and Steel.	Mica.			Mineral Oils. *Gallons.*		Nickel in Ore, Matte, etc.		Ores.				
			Crude and Cut.		Ground.					Gold Quartz, etc.	Iron.		Lead. (e)	
1897..	$56,720	$41,601	215	$61,565	$433	1,881	$230	3,415	$496,515	$2,804,801	1,198	$2,492	13,688	$522,837
1898..	48,307	53,317	231	69,513	(i)	9,530	2,061	6,696	970,581	3,587,953	236	402	19,989	1,008,147
1899..	64,112	84,532	538	148,239	(i)	4,268	1,194	6,545	994,537	3,272,702	1,677	4,966	15,443	895,349
1900..	77,325	68,610	487	136,332	20	17,934	2,660	6,120	1,040,498	14,148,543	3,925	7,689	8,995	678,859
1901..	83,439	136,357	406	146,848	2,740	19,942	2,008	4,327	958,365	24,445,156	58,401	150,657	29,747	2,512,061

Year. (h)	Ores.—*Continued.*				Phosphate of Lime.	Pyrites.		Salt. *Bushels.*		Sand and Gravel.	Slate.		Stone and Marble.	Tin M'f's
	Manganese.		Silver. (d)											
1897..	73	$4,348	127	$2,613,173	21	$275	14,219	$29,403	4,702	1,168	171,057	$75,184	(g)	$4,983	$2,764
1898..	7	1,371	211	3,519,786	232	1,090	18,752	221,564	5,559	1,139	150,270	80,952	(g)	61,080	5,578
1899..	24	882	137	2,630,281	781	9,290	11,707	27,377	5,209	1,518	162,509	93,402	(g)	66,516	3,159
1900..	57	2,521	71	1,354,053	135	2,285	13,507	32,499	15,151	3,458	227,942	102,151	(g)	240,104	3,479
1901..	36	1,945	152	2,420,750	6	120	22,146	54,357	56,461	11,238	197,065	108,509	(g)	128,039	14,481

(a) From the tables of the *Trade and Navigation of the Dominion of Canada.* The imports figures are for home consumption only. The exports are those of domestic produce. (b) Including coal dust. (c) Represents fine copper contained in ore, matte, regulus, etc. (d) Silver contents of ores. (e) Represents lead contained in ore. (f) Includes manufactures. (g) Includes alumina. (h) Fiscal years ending June 30. (i) Not reported.

MINERAL PRODUCTION OF BRITISH COLUMBIA. (a) (IN METRIC TONS AND DOLLARS.)

Year.	Coal.		Coke.		Copper.		Gold—Kg.				Lead. (b)		Silver—Kg.	
							Lode.		Placer.					
1897	896,980	$2,648,562	18,116	$89,155	2,415	$266,258	3,301	2,122,880	798	$513,530	17,618	1,390,517	170,227	3,272,836
1898	1,154,039	3,407,595	35,560	178,000	3,296	874,781	3,423	2,201,217	1,600	643,346	14,376	1,077,581	138,200	2,375,841
1899	1,314,838	3,882,396	34,799	171,255	3,503	1,351,453	4,302	2,857,573	2,092	1,344,900	9,917	878,870	91,425	1,663,708
1900	1,462,639	4,318,785	86,511	425,745	4,535	1,615,289	5,199	3,453,381	1,989	1,278,724	28,789	2,691,887	123,112	2,309,200
1901	1,554,188	4,587,630	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	146,429	2,762,230

(a) From the *Annual Reports of the Minister of Mines.* (b) Attention should be called to the discrepancy between certain of these figures and those of the Canadian Geological Survey; practically the total production of lead in the Dominion is from British Columbian ore.

MINERAL PRODUCTION OF NOVA SCOTIA. (a) (d) (IN METRIC TONS AND DOLLARS.)

Year. (c)	Coal.	Coke.	Copper	Gold. Kg.	Grindstones.	Gypsum.		Iron Ore.	Manganese Ore.		Stone, Limestone.	Tripoli and Silica.
1897.....	2,358,051	45,720	(b)	827	$32,400	126,500	(b)	48,852	102	(b)	25,300	.....
1898.....	2,317,957	42,672	(b)	967	38,000	133,096	.....	31,547	76	.....	24,384	.....
1899.....	2,684,610	56,372	(b)	864	50,000	142,240	.....	16,428	102	.....	32,512	810
1900.....	3,290,057	62,992	(b)	945	56,500	124,237	.....	15,755	8	.....	50,800	998
1901.....	3,684,581	121,960	(b)	954	815	137,852	.....	426,420	10	.....	97,359	818

(a) From the *Annual Reports of the Department of Mines of Nova Scotia.* (b) Not stated in the official reports. (c) For the fiscal year ending September 30. (d) There was also produced in 1899, 400 net tons of copper ore and 385 tons barytes; in 1900, 783 net tons barytes and 600 tons copper ore; in 1901, 600 net tons barytes and 90,084 tons pig iron.

MINERAL PRODUCTION OF ONTARIO. (a) (IN METRIC TONS AND DOLLARS.)

Year.	Arsenic.	Clay Products.									
		Brick, Common. *Number.*		Brick, Pressed.—*Number.*				Pottery.	Tiles—*Thousands.*		
				Plain.		Fancy.			Drain.		Roofing.
1897..	*Nil.*	(g)	.....	7,148,908	$53,727	895,000	$9,350	(g)	(g)	.....	(g)	$73,551
1898..	*Nil.*	170,000,000	3914,000	7,754,868	87,894	(b)	.....	$155,000	22,668	$225,000	(g)	.....
1899..	52	$4,842	233,969,000	1,313,750	10,806,000	105,000	(b)	.....	101,000	21,027	240,246	(g)	.....
1900..	275	22,725	240,430,000	1,379,590	14,271,600	141,369	(b)	.....	157,449	19,544	209,738	(g)	.....
1901..	630	41,677	259,265,000	1,530,460	16,585,000	141,394	(b)	.....	198,950	21,592	231,374	(g)	.....

Year.	Cement—*No. of Barrels.*				Copper. Metric Tons.		Gold.			Graphite.		Gypsum, Crude and Calcined. Metric Tons.	
	Natural Rock.		Portland.				Ore. Met. Tons.	Metal.					
								Kg.	Value.				
1897.....	84,670	$76,123	96,925	$170,302	2,495	$300,067	(g)	354·9	$190,944	*Nil.*	.....	1,566	$17,905
1898.....	91,528	74,222	153,348	302,096	3,798	268,080	(g)	505·8	275,078	272	$6,000	2,722	4,000
1899.....	139,487	117,039	222,550	444,227	2,571	176,237	(g)	1,164·8	419,228	1,107	16,179	1,089	16,512
1900.....	125,428	99,994	306,726	598,021	3,052	319,681	(g)	561·7	297,861	1,625	27,080	998	18,050
1901.....	188,698	107,625	350,660	563,255	4,117	589,080	(g)	446·6	244,443	907	20,000	1,410	13,400

Year.	Iron.				Lime—*Bushels.*		Mica. Metric Tons.		Natural Gas.	Nickel. Metric Tons.		Petroleum.	
	Ore.		Pig.									Crude. *Imperial Gallons.* (h)	
1897	2,507	$4,689	21,783	$288,128	(g)	.....	(g)	.....	$308,448	1,813	$359,651	25,556,591	(g)
1898	24,865	48,875	43,775	530,789	2,620,000	$308,000	31	$7,500	301,600	2,071	514,220	26,978,977	(g)
1899	15,342	30,951	58,740	808,157	4,342,500	535,000	241	38,000	440,904	2,605	526,104	23,615,967	(g)
1900	81,921	111,805	56,596	936,066	3,893,000	544,000	552	81,550	392,823	3,211	756,626	23,331,783	$1,869,045
1901	247,308	174,428	105,599	1,701,703	4,100,000	550,000	337	37,219	336,183	4,080	1,859,970	21,433,500	1,467,940

Year.	Petroleum.—*Continued.*								Salt. Metric Tons.	
	Refined Products. (h)									
	Illuminating Oils. *Imp. Gals.*		Lubricating Oils. *Imp. Gals.*		All Other Oils. *Imp. Gals.* (c)		Paraffine Wax. Metric Tons.	(e) Fuel Products		
1897.....	10,891,337	$1,131,083	1,959,810	$199,755	949,341	$77,340	970·4	$88,378	$281,085	49,611	$249,880
1898.....	12,281,622	1,243,490	2,043,226	202,150	1,240,967	121,840	1,186·6	116,349	286,705	53,874	278,886
1899.....	11,697,910	1,059,485	2,087,475	189,294	1,394,530	148,963	1,266·8	136,066	213,544	51,143	317,412
1900.....	11,783,755	1,076,242	1,980,428	232,805	1,463,599	174,346	2,086·4	184,718	200,934	60,408	327,477
1901.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	54,744	323,058

Year.	Sewer Pipe.	Silver.		Stone. Total Value.	Terra Cotta.	Total Value. (f)
		Kg.	Value.			
1897....	$73,251	*Nil.*	.....	.....	$35,800	$3,899,821
1898....	96,717	2,095·5	$51,960	$750,000	(b)	7,201,891
1899....	138,356	3,280·4	65,575	1,041,350	(b)	8,785,251
1900....	130,635	4,995·9	96,367	650,342	(b)	9,242,044
1901....	147,948	4,916·2	84,880	850,000	(b)	11,892,525

(a) From the *Annual Reports of the Bureau of Mines of Ontario*, Toronto. (b) Quantity and value included with that of plain pressed brick. (c) Comprises benzine and naphtha. (e) Comprises gas and fuel oils and tar. (f) In 1898 total includes 521 metric tons carbide of calcium ($34,447). In 1899, 5,300,000 paving brick ($42,550); 965 metric tons carbide of calcium ($74,680); 91 metric tons of talc ($500); and 1,069 metric tons of zinc ($84,000). In 1900, 454 metric tons zinc ore ($500); 3,211 tons steel ($756,636); 3,629 tons feldspar ($5,000); 907 tons talc ($5,000). In 1901, 1,361 metric tons zinc ore ($1,500); 13,131 tons steel ($347,280); 4,628 tons feldspar ($6,375); 363 tons talc ($1,400;) 6,352 tons iron pyrites ($17,500;) 485 tons corundum ($58,115); 2,515 tons carbide of calcium ($168,792); 473 tons actinolite ($3,126). (g) Not reported. (h) One barrel of crude oil is reckoned at 35 imperial gallons, and 1 barrel refined at 42 imperial gallons.

CHILE.

THERE are no official statistics of mineral production in Chile. The exports and imports are summarized in the subjoined table. With respect to the most important articles of mineral production, namely, copper and nitrate of soda, the exports practically represent the production. This is also the case with respect to iodine and borate of lime.

MINERAL EXPORTS OF CHILE. (*a*) (IN METRIC TONS AND CHILEAN DOLLARS.)

Year.	Borate of Lime.		Borax.		Clay.		Coal.		Cobalt Ore.		Copper Matte.	
1896....	7,486	$374,294	(*b*)	.....	40	$600	204,858	$1,434,253	(*b*)	.....	2,528	$284,897
1897....	3,154	288,770	14	$2,860	20	998	243,968	1,869,310	6·0	$312	2,519	251,915
1898....	7,028	1,124,509	6	3,391	(*b*)	.....	282,663	4,239,943	18·2	1,817	3,079	861,999
1899....	14,951	2,242,618	14	7,214	20	1,000	241,995	4,839,900	55·0	8,181	1,710	684,965
1900....	13,177	1,317,676	27	13,314	*Nil.*	.....	325,042	3,900,460	26·8	4,027	4,838	1,935,165

Year.	Copper and Silver Matte.		Copper, Silver and Gold Matte		Copper Ore.		Copper and Silver Ore.		Copper, Silver and Gold Ore—Kg.		Copper, in Bars.	
1896....	1,059	$213,115	7·6	$1,520	6,159	$307,943	62·3	$9,462	29,542	$2,954	20,592	$5,148,015
1897....	904	378,340	(*b*)	.....	3,396	169,810	161·8	25,455	(*b*)	.....	19,011	5,226,199
1898....	419	167,556	17·8	29,133	20,301	2,022,730	87·0	17,392	5,733	1,300	20,600	13,759,498
1899....	1,094	546,880	93·0	37,162	35,854	3,585,443	184·0	36,799	12,000	2,633	17,311	14,928,273
1900....	1,918	1,150,836	241·8	145,067	20,213	2,021,267	288·5	40,722	360	90	20,340	17,899,200

Year.	Fire Clay Kg.		Gold Bullion. Kg.		Gold Ore.		Iodine.		Iron Ore.		Lead and Argentiferous Lead, in Bars.	
1896....	(*b*)	.....	1,061·3	$849,036	367	$73,475	206	$2,063,950	(*b*)	.....	594	$59,415
1897....	8,200	$82	1,131·7	905,168	64	28,535	243	2,429,370	5·1	$256	369	66,696
1898....	30,440	1,218	1,630·5	2,445,735	8	2,554	295	3,169,570	(*b*)	.....	13	13,506
1899....	*Nil.*	.....	1,625·0	2,461,234	12	6,051	304	4,108,427	(*b*)	.....	171	34,221
1900....	*Nil.*	.....	1,871·1	2,806,698	129	57,468	318	4,043,172	(*b*)	.....	14	6,706

Year.	Lime.		Manganese Ore.		Mineral Specimens.	Chile Saltpeter.		Silver Ore.		Silver and Gold Ore.	
1896	4·0	$80	26,151	$261,515	$700	1,111,757	$43,931,667	2,750	$1,257,870	666	$130,182
1897....	0·8	24	23,529	1,411,648	20,300	1,057,640	37,461,559	984	434,231	260	46,631
1898....	0·7	21	20,851	447,028	1,400	1,394,227	90,675,297	284	205,386	269	57,685
1899....	1·0	42	40,931	1,227,922	64,521	1,380,718	96,650,282	302	247,597	370	129,416
1900....	0·3	10	25,715	761,406	3,550	1,465,935	109,945,156	225	130,947	217	34,249

Year.	Silver, in Bars, etc. Kg.		Silver, Old. Kg.		Silver-Lead Ore.		Silver Sulphuret Ore.		Tin.	
1896....	151,226	$4,183,108	988	$19,754	0·8	$83	160	$418,785	(b)	.....
1897....	143,541	3,781,125	443	12,518	6·0	636	183	388,062	48	$54,613
1898....	139,756	6,987,816	55	2,219	11·8	1,557	290	434,740	8	4,900
1899....	75,899	3,791,589	(b)	.....	32·0	4,844	339	1,017,110	8	4,979
1900....	45,623	2,506,497	140	5,333	1·4	218	172	863,332	0·2	103

(a) From the *Estadistica Commercial de la Republica de Chile*, Valparaiso. It will be noticed that the values reported vary widely for the different years. This is probably to be referred to the fluctuations of the currency standard. (b) Not reported.

MINERAL IMPORTS OF CHILE. (a) (IN METRIC TONS AND CHILEAN DOLLARS.)

Year.	Bitumen for Pavements.		Brass.		Cement, Roman.		Coal.		Copper.			
									Sheets.		For Various Uses	
1895....	190	$38,901	82	$96,776	18,236	$365,550	574,063	$4,578,067	18	$9,780	57	$15,473
1896....	254	52,198	118	50,518	14,431	326,395	683,196	5,462,954	16	9,484	54	29,853
1897....	237	55,892	60	26,206	18,205	365,129	518,421	4,122,918	55	28,333	43	23,834
1898....	83	52,473	.....	.....	16,905	676,199	656,202	13,173,965	57	44,002	.....	.....
1899....	84	62,988	*Nil.*	.....	16,166	646,588	623,527	12,469,478	75	57,343	.....	.....

Year.	Copper, Sulphate.		Earth for Smelting Furnaces.		Gold Coin.	Iron.							
						Bars and Ingots		Hoops.		Sheets, Ungalv.		Sheets, Galv.	
1895....	134	$18,855	177	$3,980	$392,900	16,506	$772,728	1,198	$84,794	4,714	$375,848	5,97	$719,721
1896....	111	16,643	69	1,386	5,635	13,970	698,611	1,452	101,605	1,256	99,985	7,912	942,440
1897....	85	10,737	100	3,542	4,440	7,604	354,592	802	63,943	1,859	153,782	10,757	1,292,176
1898....	218	65,358	30	1,785	*Nil.*	10,223	1,256,190	404	54,268	2,283	292,353	9,946	1,377,243
1899....	188	56,312	25	1,178	*Nil.*	8,224	870,768	913	120,831	2,553	234'995	3,837	525,250

Year.	Lead, Bars and Sheets.		Quicksilver.		Salt.				Silver.					
					Common.		Refined.		Bars—Kg.		Coin.		Ore.	
1895....	194	$27,750	106	$106,277	3,192	$23,042	246	$12,116	17·3	$954,255	$112,430		58	21,3833
1896....	525	73,519	54	54,350	7,311	53,486	353	19,077	.....	.....	89,853		40	14,6400
1897....	281	37,832	40	39,758	13,179	90,742	320	16,191	.....	.....	26,230		9	3,0300
1898....	118	28,339	15	44,435	1,543	30,865	101	10.111	.....	.....	*Nil.*		21	5,4555
1899....	70	16,742	21	63,306	397	7,971	38	3,823	.....	.....	*Nil.*		1	6555

Year.	Soda, Caustic.		Steel, Bars and Sheets.		Sulphur.		Tin.		Whiting and Gypsum.		Zinc.			
											Bars.		Sheets.	
1895....	2,111	$123,102	7,142	$857,400	1,679	$100,961	804	$113,046	796	$20,674	7	$944	309	$55,830
1896....	2,570	149,222	3,480	422,078	1,775	110,742	506	71,648	1,492	47,631	3	426	315	45,451
1897....	2,604	155,026	2,225	268,181	2,655	157,671	608	82,149	492	13,683	24	3,314	252	50,236
1898....	2,796	341,760	1,389	166,263	3,317	331,725	51	58,173	466	22,028	73	18,213	282	83,268
1899....	1,135	141,461	1,686	203,633	306	30,624	45	57,059	410	20,192	104	33,133	79	24,607

(a) From the *Estadistica Commercial de la Republica de Chile*, Valparaiso.

CHINA.

THERE are no official statistics of mineral production in China. The exports and imports as reported by the Imperial Maritime Customs officials are summarized in the following tables:

MINERAL IMPORTS OF CHINA. (*a*) (IN METRIC TONS AND DOLLARS.)

Year.	Brass Wire.		Cement.		Chinaware, Fine and Coarse.		Coal.		Colors.		Copper. Bar, Rod, Sheets, Plates, Nails.	
1897....	133·6	$33,915	(*b*)	$79,056	401·3	$109,119	558,149	$2,658,723	2,135·6	$138,723	499·6	$108,317
1898....	188·2	46,116	18,342	323,947	379·1	92,522	742,296	3,696,434	(*b*)	130,359	393·7	84,244
1899....	141·2	46,881	14,401	278,479	510·0	134,399	873,080	4,669,570	(*b*)	210,856	250·9	80,690
1900....	126·9	39,603	(*b*)	112,437	481·6	79,419	878,373	4,791,312	(*b*)	221,625	351·3	126,213
1901....	94·8	28,629	(*b*)	72,444	353·2	44,012	1,171,882	6,013,679	(*b*)	179,348	80·2	33,584

Year.	Copper—*Continued.* Slabs and Ore, Unmanufactured		Wire.		Wares, Unclassified.		Flint Stones.		Glass. Window—*Boxes.*		Wares.	
1897....	2,525·8	$606,602	79·9	$20,743	34·4	$13,975	2,652·9	$30,707	188,553	$335,532	$238,784	
1898....	1,817·7	429,702	80·6	21,718	23·0	8,382	2,868·7	32,339	93,409	222,611	247,588	
1899....	1,191·4	402,053	28·7	9,567	61·6	29,247	2,010·0	23,826	116,896	350,272	264,948	
1900....	1,083·5	395,649	69·4	25,396	95·9	46,863	765·5	10,836	100,021	282,492	240,612	
1901....	620·4	222,892	47·5	16,917	69·5	30,042	2,589·1	24,379	73,147	203,510	367,895	

Year.	Iron. Bar.		Hoop.		Nail-Rod.		Old.		Pig and Kentledge.		Sheets and Plates.	
1897....	6,367·9	$209,284	1,480·8	$54,326	11,611·4	$353,935	32,881	$587,278	1,458·5	$36,678	3,489·6	$164,302
1898....	11,309·6	352,081	1,923·3	70,683	21,253·6	643,671	43,018	798,206	10,179·2	280,540	4,709·2	215,454
1899....	8,518·8	334,114	1,211·9	51,004	12,837·8	505,612	38,599	760,297	2,780·3	71,969	6,595·2	270,908
1900....	7,154·1	308,454	980·8	50,736	7,477·2	310,833	26,570	601,476	1,301·8	27,048	8,619·3	561,117
1901....	12,056·4	503,271	1,284·7	57,781	11,534·1	448,170	29,077	636,244	4,155·2	82,113	4,154·3	232,448

Year.	Iron—*Continued.* Wire.		Wares, Unclassified	Jadestone.		Lead. Pig.		Tea and Sheet.		Machinery
1897....	2,529·1	$163,455	$299,645	227·5	$174,467	7,709	$494,721	102·2	$7,271	$1,956,051
1898....	2,968·0	184,461	384,550	249·5	195,311	8,832	587,558	101·2	7,500	1,231,031
1899....	2,934·7	188,990	490,551	221·5	115,768	9,342	703,030	109·4	10,440	1,114,382
1900....	2,192·7	175,182	572,847	164·7	91,941	2,199	410,591	130·2	15,060	1,087,568
1901....	4,158·5	273,717	564,575	217·4	110,706	7,658	524,298	460·9	44,356	878,880

Year.	Metals, Unclassed.	Nickel.		Paints.	Petroleum—*Liters.* (Refined.)		Quicksilver.		Spelter.	
1897.....	$197,659	37·0	$23,334	$457,608	451,387,592	$9,575,378	55·3	$54,023	1,819·5	$169,636
1898.....	247,345	67·9	43,392	513,659	366,728,870	8,340,289	70·4	67,481	623·1	71,684
1899.....	260,873	104·3	49,560	580,541	353,653,228	9,491,199	50·9	58,305	(*b*)	78,045
1900.....	486,608	75·8	49,931	401,338	334,320,096	10,466,685	57·1	65,050	134·2	15,495
1901.....	276,287	68·7	50,970	522,806	524,474,024	12,451,293	41·7	54,219	75·7	9,581

Year.	Steel.				Tin.				White Metal. (German Silver)		Yellow Metal. Bar, Rod, Sheets, and Nails.	
	Common.		Mild, or Iron Ingots.		Plates.		Slabs.					
1897....	3,206·9	$198,455	711·4	$22,223	3,543·7	$209,447	4,128·9	$1,396,302	241·4	$122,901	1,753·6	$317,137
1898....	2,908·7	183,523	9,109·9	232,763	6,775·6	393,620	3,198·5	1,131,619	230·4	116,859	1,678·4	297,908
1899....	5,045·9	323,886	8,699·2	326,589	1,121·7	76,264	2,292·4	1,068,765	162·6	84,989	1,588·2	328,610
1900....	3,715·9	274,077	6,511·1	282,452	2,082·9	225,471	3,320·7	1,429,993	155·7	94,088	1,406·6	323,334
1901....	3,166·3	216,559	7,973·2	251,909	4,962·4	419,060	4,286·2	2,039,361	176·2	100,577	1,442·0	287,442

RE-EXPORT OF FOREIGN GOODS FROM CHINA. (*a*) (IN METRIC TONS AND DOLLARS.)

Year.	Cement.		Chinaware.		Coal.		Colors.		Copper, Bar, Rod Sheets, Plates and Nails.		Glass.		
											Window. *Boxes.*		Wares.
1897....	147·0	$1,935	0·1	$128	47,354	$233,561	33·8	$8,578	5·08	$1,008	1,024	$2,580	$1,992
1898....	122·4	2,088	0·1	81	55,238	284,501	(*b*)	5,880	(*d*) 1·93	517	1,378	3,459	2,675
1899....	57·6	889	0·2	40	64,209	347,305	(*b*)	7,997	(*d*) 6·42	2,275	683	1,901	2,014
1900....	(*b*)	128	0 7	162	54,208	267,513	(*b*)	4,734	(*d*)27·09	9,795	2,310	6,705	3,141
1901....	(*b*)	20,744	(*b*)	.....	65,053	309,777	(*b*)	4,384	(*d*)72·36	17,454	5,460	15,292	1,536

Year.	Iron.								Lead—In Pigs.		Metals, Unclassed.
	Bar, Hoop, Nail-Rod, Sheets, Plates, and Wire.		Old.		Pig and Kentledge.		Wares, Unclassed.				
1897....	1,691·5	$69,655	258·5	$5,008	1,181·6	$33,774	$6,340		68·6	$4,981	$5,650
1898....	1,155·9	57,249	342·5	7,467	707·1	19,650	11,000		72·7	5,284	12,693
1899....	1,166·9	57,314	365·0	7,185	2,860·1	67,177	7,654		0 1	10	5,279
1900....	1,025·0	62,097	323·6	6,513	244·4	5,352	10,227		82·2	9,837	9,396
1901....	820·5	49,596	275·4	6,394	171·8	3,614	4,973		0·6	45	28,840

Year.	Nickel.		Paints.	Petroleum—*Liters.* (Refined.)		Quicksilver.		Spelter.		Steel.	
1897.....	3·443	$1,874	$15,996	1,982,607	$42,623	2·6	$2,639	12·08	$1,182	591·0	$90,695
1898.....	4·654	2,952	15,016	2,585,556	59.441	4·1	4,026	(*b*)	.....	789·6	28,179
1899.....	1·212	772	22,718	50,160	1,505	1·0	1,177	(*b*)	.....	615·6	23,550
1900.....	27·879	17,856	13,674	1,971,200	63,636	3·9	4,821	(*b*)	.....	499·2	21,144
1901.....	4·808	3,155	7,129	643,850	18,759	1·7	2,056	(*b*)	.....	592·1	26,950

RE-EXPORT OF FOREIGN GOODS FROM CHINA. *Concluded.*

Year.	White Metal. (German Silver)		Tin, in Slabs and Tinplates.		Yellow Metal, Bar, Rod, Sheets and Nails.	
1897....	1·8	$711	271·1	$32,480	0·2	$52
1898....	0·2	91	127·5	27,999	13·6	2,928
1899....	1·2	696	701·2	73,310	1·3	468
1900....	1·2	711	258·7	53,043	0·06	21
1901....	0·8	433	298·9	34,752	0·25	45

EXPORT OF NATIVE GOODS FROM CHINA. (*a*) (IN METRIC TONS AND DOLLARS.)

Year.	Chinaware, Earthenware, and Pottery.		Glassware, Bangles, etc.		Gold and Silver Ware.	
1897...	20,453	$996,722	1,066·9	$252,573	2·597	$98,575
1898...	20,381	1,053,015	1,261·9	300,919	3·325	112,530
1899...	22,605	1,316,032	1,245·1	313,712	3·576	126,358
1900...	21,396	1,220,526	1,005·4	279,076	4·902	193,796
1901...	20,396	1,218,544	1,163·9	286,837	4·558	156,356

(*a*) From the *Returns of Trade and Trade Reports of the Imperial Maritime Customs*, Shanghai, China. In these reports the unit of quantity is chiefly the "picul," and that of value the "Haikwan-tael." In converting the original data to metric tons and dollars, the following relations were used: 1 picul = 0·060453 metric ton; in 1897, 1 Haikwan-tael = 72c.; in 1898, 70c.; in 1899, 71·4c.; in 1900, 71·7c.; in 1901, 74·2c., at the average sight exchange on New York, London, Paris, Berlin, Calcutta, and Hong-Kong respectively. (*b*) Not reported. (*d*) In 1898 there was also exported 4·41 metric tons of unclassed copperware valued at $1,821; in 1899, 0·25 metric tons ($153); in 1900, 0·42 metric tons ($213); in 1901, 0·12 metric tons ($47).

FRANCE.

THE official statistics of mineral production in France and her Colonies are summarized in the subjoined tables. With respect to the most important substances, reference should be made to the respective captions elsewhere in this volume.

MINERAL PRODUCTION OF FRANCE. (*a*) (IN METRIC TONS; 5 f.—$1.)

Year.	Alunite.		Antimony Ore.		Asphaltum.		Barytes.		Bauxite.		Bituminous Substances. (*c*)	
1896..	171	$1,710	5,675	$68,544	17,717	$150,263	2,791	$8,257	33,820	$48,833	225,784	$348,187
1897..	(*b*)	.....	4,685	64,915	17,982	146,272	3,209	8,736	41,740	55,211	233,828	339,898
1898..	(*b*)	.....	4,433	65,046	18,832	153,758	2,763	7,338	36,723	67,133	229,106	333,888
1899..	(*b*)	.....	7,392	140,093	22,100	172,380	4,058	11,524	48,215	83,967	258,449	360,657
1900..	(*b*)	.....	7,843	112,803	24,400	180,560	3,635	10,483	58,530	92,596	266,474	393,429

Year.	Cement.		Clay Products.				Coal.					
			Potters' Clay.		Refractory Clay.		Coal.		Lignite.		Peat.	
1896..	934,624	$4,556,503	246,677	$233,340	291,690	$311,614	28,750,452	$62,516,853	439,448	$776,988	130,207	$329,047
1897..	976,813	4,716,471	270,292	243,200	318,185	333,428	30,337,207	66,020,171	460,422	781,517	98,067	253,851
1898..	1,072,025	5,359,620	260,362	203,344	295,913	348,532	31,826,127	71,701,384	529,977	929,300	104,265	301,486
1899..	1,144,271	5,733,404	310,220	272,176	367,432	375,891	32,256,148	80,412,382	606,564	1,096,181	99,230	302,637
1900..	1,147,670	5,796,320	331,396	258,717	329,561	339,951	32,721,502	98,362,014	682,786	1,487,314	95,690	280,988

Year.	Copper Ore.		Fluorspar.		Gypsum.				Iron Ore.		Lead-Silver Ore.	
					Crude.		Calcined.					
1896..	106	$704	1,940	$6,068	264,187	$241,608	1,429,550	$2,516,112	4,069,390	$2,565,205	19,042	$450,709
1897..	956	3,645	2,722	8,160	292,753	264,845	1,369,269	2,458,337	4,582,236	3,008,028	21,212	556,261
1898..	382	2,841	3,077	9,231	303,531	281,690	1,449,884	2,596,870	4,731,394	3,207,447	23,342	640,226
1899..	2,021	64,416	5,140	15,898	263,879	261,192	1,372,067	2,475,616	4,985,702	3,640,115	17,505	543,146
1900..	3,081	151,090	3,430	10,341	192,916	192,679	1,405,845	2,579,542	4,676,740	3,545,312	24,276	721,716

Year.	Lime.		Manganese Ore.		Millstones.		Mineral Paints. (Ochers.)		Petroleum, Crude.		Phosphate Rock.	
1896..	2,224,847	$5,599,917	31,318	$185,717	28,237	$224,347	27,499	$129,704	9,292	$209,184	582,667	$3,502,028
1897..	2,201,428	5,682,323	37,212	208,035	32,175	244,083	32,299	156,180	10,233	234,811	535,390	2,854,882
1898..	2,339,850	5,975,874	31,935	166,211	*g*34,929	727,295	33,780	158,014	9,694	221,172	568,558	3,115,958
1899..	2,343,877	6,081,922	39,897	223,337	41,535	765,242	32,750	161,473	(*b*)	.....	645,868	3,334,145
1900..	2,377,110	6,330,193	28,992	170,089	41,103	730,234	33,080	164,000	(*b*)	.....	587,919	2,827,291

Year.	Pyrites.		Salt.		Slate.				Stone.	
					Roofing.		Slabs.		Building.	
1896..	282,064	$712,986	1,042,614	$2,473,568	283,352	$3,154,551	1,148	$31,006	10,089,845	$9,084,571
1897..	303,488	752,658	948,003	2,239,824	310,820	3,620,949	1,143	31,282	10,105,438	9,355,103
1898..	310,972	785,242	999,283	2,115,120	316,911	4,118,789	1,318	38,552	9,989,416	9,890,737
1899..	318,832	827,623	1,193,552	2,506,832	299,307	3,615,362	1,162	36,003	10,587,789	10,445,644
1900..	305,073	779,925	1,088,634	2,415,973	290,204	3,439,981	1,325	39,400	9,974,347	9,612,391

Year.	Stone.—*Continued.* Limestone. (Flux.)		Marble.		Paving Blocks.		Sulphur Ore. (*d*)		Zinc Ore.	
1896....	721,296	$211,511	119,168	$907,257	677,213	$2,157,963	9,720	$25,660	81,346	$1,160,021
1897....	709,562	196,777	118,675	927,184	566,677	1,918,105	10,723	31,252	83,044	1,305,008
1898....	695,501	200,660	124,161	998,831	568,483	1,898,678	9,818	27,141	85,550	1,475,581
1899....	924,945	246,645	191,080	1,406,773	621,799	2,107,324	11,744	38,884	84,813	1,915,402
1900....	1,040,805	256,351	154,414	1,228,066	659,125	2,326,747	11,551	26,427	67,059	1,222,299

METALLURGICAL PRODUCTION OF FRANCE. (*a*) (IN METRIC TONS; 5 f.—$1.)

Year.	Aluminum.		Antimony.		Copper.		Gold—Kg.		Iron and Steel. Iron, Pig.		Iron, Wrought.	
1896....	370	$259,000	969	$130,217	6,544	$1,641,876	327	$225,687	2,839,537	$26,476,584	828,758	$25,343,590
1897....	470	285,500	1,083	141,857	7,376	1,845,243	276	190,109	2,484,191	29,121,027	584,540	24,406,664
1898....	565	301,800	1,226	163,200	7,834	2,270,200	267	183,900	2,525,100	31,858,400	766,000	25,221,800
1899....	763	401,500	1,499	243,800	6,640	2,419,060	270	186,000	2,578,400	37,342,000	894,000	30,765,400
1900....	1,026	525,600	1,573	246,080	6,446	2,365,600	208	139,800	2,714,298	44,318,800	672,000	28,663,400

Year.	Iron and Steel—*Con* Steel. (*e*)		Lead. (*f*)		Nickel.		Silver—Kg.		Zinc.	
1896.....	916,617	$41,898,067	8,282	$444,871	1,545	$921,500	70,479	$1,592,825	35,585	$2,922,628
1897.....	994,891	45,276,658	9,916	630,928	1,245	741,500	80,351	1,639,160	38,067	3,263,490
1898.....	1,174,000	55,042,800	10,920	738,400	1,540	920,000	90,583	1,817,000	37,155	3,598,600
1899.....	1,240,000	64,877,400	15,981	1,343,500	1,740	1,040,000	82,105	1,642,100	39,274	4,508,400
1900.....	1,565,104	70,813,000	15,210	1,253,320	1,700	1,020,000	85,646	1,712,920	36,305	3,569,680

(*a*) From *Statistique de l'Industrié Minérale.* (*b*) Not reported. (*c*) Includes pure bitumen, bituminous schist, bituminous sand, and asphaltic limestone. (*d*) Sulphur and limestone impregnated with sulphur. (*e*) Wrought steel. (*f*) Lead produced from native ores only, and does not include the metal produced from foreign ores and bullion. (*g*) Finished product.

MINERAL IMPORTS OF FRANCE. (*a*) (IN METRIC TONS; 5 f.—$1.)

Year.	Bituminous Substances. (*b*)		Coal. (*c*)		Copper.		Gold.	Silver.	Iron and Steel.		Iron, Cast. (Crude.)	
1897..	29,931	$419,000	10,457,255	$37,894,400	54,460	$14,375,400	$58,143,077	$42,468,798	60,804	$1,954,800	35,638	$944,400
1898..	20,385	244,600	10,445,090	41,438,200	52,976	14,998,000	39,881,575	38,274,504	47,325	1,941,800	(*d*)	998,000
1899..	30,770	369,200	11,896,080	51,646,600	58,419	20,450,000	63,697,020	37,528,657	64,178	3,288,400	(*d*)	2,182,200
1900..	39,598	475,200	14,601,981	81,366,600	61,638	21,628,800	90,408,723	29,164,546	118,152	5,315,600	(*d*)	3,151,400
1901..	28,898	346,600	13,929,120	77,504,600	47,119	16,684,400	85,656,800	19,555,400	77,742	3,641,800	(*d*)	1,618,200

Year.	Lead.		Nickel.		Sodium Nitrate	Stone.	Sulphur.		Tin.		Zinc.	
1897..	86,589	$6,661,800	316	$475,400	$8,105,400	$2,675,800	136,118	$2,602,200	7,642	$2,572,000	81,211	$2,998,800
1898..	74,902	5,843,600	330	525,000	8,026,400	2,814,600	130,289	2,800,400	9,247	3,475,800	82,342	3,682,400
1899..	67,149	6,657,400	286	399,600	9,341,600	4,494,800	120,062	2,813,000	6,907	4,495,400	25,516	3,467,600
1900..	76,857	7,749,200	299	397,740	11,995,820	5,144,400	133,531	3,140,200	7,324	4,758,200	33,144	3,906,800
1901..	58,535	6,397,600	252	421,200	9,653,000	4,056,800	101,301	2,601,200	7,348	5,105,000	29,722	3,477,600

Year.	Alum.	Borax.	Bromides.	Cement	Chromate of Potash and of Soda.	Copper Ore.	Hydrochloric Acid.	Iron. Ore.	Iron. Pyrites.
1897.....	54	264	18	15,141	2,852	11,960	2,119	2,137,860	69,470
1898.....	27	139	30	11,280	2,890	8,779	1,994	2,032,240	71,569
1899.....	34	123	46	13,640	3,147	8,517	1,905	1,950,665	109,696
1900.....	23	111	36	13,612	3,293	9,766	1,962	2,1.9,003	156,825
1901.....	39	127	22	16,210	2,784	13,383	1,903	1,662,875	206,432

Year.	Kaolin.	Lead Ore.	Lead Carbonate.	Lime, Chloride.	Lime.	Manganese Ore.	Mercury	Nitrate of Potash.	Nickel Ore.	Nitric Acid.
1897.....	42,384	13,981	1,327	1,718	321,647	85,512	248	1,309	17,441	774
1898.....	40,352	14,377	1,376	1,288	346,000	100,243	221	1,006	24,935	992
1899.....	36,904	12,637	2,029	1,887	321,610	106,630	276	1,015	28,620	1,282
1900.....	39,842	19,772	1,739	1,215	399,092	120,790	161	1,998	17,697	1,140
1901.....	41,972	15,481	1,789	1,400	374,280	94,365	205	757	39,497	961

Year.	Oxides.						Petroleum.	Phosphates.	Plaster.	Platinum. Kg.	Potash and Carbonate of.	Potassium Chloride.
	Cobalt	Copper.	Iron.	Lead.	Uranium.	Zinc.						
1897.....	9	29	1,125	1,759	5	1,114	288,671	313,608	1,869	1,069	1,769	11,620
1898.....	9	52	1,021	1,874	15	1,256	291,961	336,842	2,040	505	2,418	10,229
1899.....	9	36	1,037	1,907	44	1,765	306,078	242,021	2,260	817	2,779	13,335
1900.....	9	84	1,022	1,284	36	1,743	302,482	283,921	3,648	2,398	2,768	13,594
1901.....	9	162	1,001	1,383	22	1,333	295,335	235,422	2,840	1,857	2,590	13,299

Year.	Sal Ammoniac.	Salt.	Soda, Caustic	Sulphates.		Sulphide of Mercury.	Sulphuric Acid.	Superphosphate of Lime.	Tin Ore.	Zinc Ore.
				Copper.	Iron.					
1897.....	27,454	32,917	1,378	30,182	1,353	24	3,147	195,353	149	58,074
1898.....	20,426	35,353	1,772	30,897	896	19	4,666	178,569	357	60,481
1899.....	12,210	37,970	1,494	21,733	1,698	21	4,583	171,681	486	78,192
1900	15,205	32,045	1,062	22,820	1,589	23	4,254	143,487	512	66,178
1901.....	9,265	26,260	869	15,313	45	23	5,386	168,060	367	74,553

MINERAL AND METALLURGICAL EXPORTS OF FRANCE. (*a*) (IN METRIC TONS.)

Year.	Aluminum.	Antimony.		Cement	Coal.	Copper.		Gold. Kg. (*e*)	Iron.				Iron Pyrites
		Ore.	Metal			Ore.	Metal		Ore.	Pig.	Bars.	Steel.	
1897 ..	224	623	61·4	244,504	1,142,195	2,000	12,667	3,335	299,589	108,645	39,894	45,809	54,367
1898....	199	616	100·6	241,150	1,320,616	1,788	14,350	1,812	236,169	162,991	27,424	47,278	60,406
1899....	256	304	254·7	244,480	1,229,090	2,078	17,949	2,622	291,346	153,792	29,112	33,584	53,395
1900....	324	153	336·2	231,450	1,201,210	9,197	16,791	883	371,799	114,361	18,763	19,535	61,530
1901....	308	466	373·7	242,720	1,053,675	16,359	18,167	902	259,227	97,122	29,210	21,614	52,954

Year.	Lead.		Manganese Ore.	Millstones and Pieces. *Number.*	Nickel. Refined	Phosphate Rock.	Plaster.	Silver. Kg. (*f*)	Tin.	Zinc.	
	Ore.	Metal.								Ore.	Metal.
1897....	12,007	10,364	19,464	158,979	498	69,188	107,823	5,874	651	79,909	10,977
1898....	10,216	3,663	12,229	203,584	526	93,742	106,790	1,886	587	60,664	16,995
1899....	3,909	1,163	12,289	112,620	280	70,517	112,580	.....	666	76,104	14,958
1900....	2,345	958	8,392	65,561	598	89,135	231,450	15,470	716	54,665	12,712
1901 ...	1,845	4,749	5,647	52,383	530	80,522	202,160	17,440	1,272	43,075	16,145

(*a*) The figures are from *L'Economiste Français*, and represent the *Commerce Spécial* of France. (*b*) Includes bitumen, bituminous schist and sand, and asphaltic limestone. (*c*) Including coke. (*d*) Not reported. (*e*) Gold and platinum, in ore, sheets, leaves, or threads. (*f*) Silver in ore, sheets, leaves, or threads.

MINERAL PRODUCTION OF ALGERIA. (IN METRIC TONS AND DOLLARS; 5 f. = $1.)

Year.	Antimony Ore.		Cement.		Clays.		Copper Matte.		Gypsum, Crude.		Gypsum, (Plaster).		Iron. Ore.	
1896..	658	$18,957	60	$300	48,297	$42,526	427	$39,028	300	$138	29,870	$114,123	374,476	$563,946
1897..	781	21,621	...	.....	67,180	59,607	289	28,380	350	175	29,120	109,473	441,467	663,282
1898..	138	4,416	...	.....	78,600	60,275	488	54,200	150	75	29,750	110,585	473,569	703,667
1899..	200	10,400	...	.....	88,600	73,874	472	43,700	200	100	31,800	117,795	550,921	932,336
1900..	98	3,175	...	.....	94,000	76,140	...	.....	500	250	37,100	138,940	174,000	268,321

Year.	Iron—Con. Cast, 2d Fusion.		Lead-Silver Ore.		Lime. Hydraulic.		Lime. White.		Marble.		Onyx.	
1896	577	$35,490	117	$2,186	20,000	$120,000	9,450	$36,480	900	$36,100	900	$25,530
1897	699	44,870	145	3,041	20,425	122,500	9,215	32,260	1,660	26,150	364	25,480
1898	*Nil.*	.....	120	3,120	13,000	78,000	12,975	46,788	985	30,004	219	12,483
1899	*Nil.*	.....	389	10,482	12,000	72,000	13,645	48,961	235	438	217	12,397
1900	*Nil.*	.....	222	6,382	12,000	72,000	13,700	49,050	(*b*)	.....	228	12,976

Year.	Phosphate Rock.		Quicksilver Ore.		Salt.		Sand and Gravel.		Zinc Ore.	
1896	165,738	$500,905	8	$500	19,658	$85,122	41,400	$8,280	17,587	$168,768
1897	228,141	912,564	.....	.....	23,222	78,058	80,860	20,280	32,269	301,538
1898	269,500	1,078,000	.....	.....	21,300	86,000	72,185	17,717	29,800	281,400
1899	324,983	1,299,932	.....	.....	17,378	67,300	72,760	15,827	42,970	502,579
1900	319,422	1,277,688	.....	.....	18,225	76,288	71,860	14,569	30,281	907,594

MINERAL PRODUCTION OF NEW CALEDONIA. (*a*) (IN METRIC TONS.)

Substances.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.
Chrome iron ore	4,343	512	242	2,927	8,079	20,186	3,949	7,712	12,634	10,474
Cobalt ore	1,343	2,200	2,200	4,112	4,277	*c*4,823	3,200	2,373	3,294	2,488
Copper ore	199	(*b*)	(*b*)	(*b*)	(*b*)	(*b*)	2,200	*Nil.*	6,349	2
Copper regulus	152	(*b*)	(*b*)	(*b*)	(*b*)	(*b*)	.....	(*b*)	(*b*)	(*b*)
Lead ore	286	(*b*)	(*b*)	(*b*)	(*b*)	(*b*)	200	(*b*)	(*b*)	(*b*)
Nickel ore	60,921	83,114	69,614	61,243	29,623	6,417	26,464	74,614	108,908	100,319

(*a*) From *Statistique de l'Industrie Minérale.* (*b*) Not stated in the reports. (*c*) Exports.

MINERAL PRODUCTION OF TUNIS. (*a*) (IN METRIC TONS AND DOLLARS.)

Year.	Salt.		Lead Ore.		Zinc Ore.	
1896	5,500	$22,000	(*b*)	.....	12,100	$118,600
1897	8,100	32,400	2,123	$26,960	11,830	147,200
1898	7,300	33,200	2,875	37,680	21,477	185,520
1899	8,850	35,400	2,263	53,400	20,079	313,400
1900	9,160	128,240	2,456	11,600	16,596	221,600

(*a*) From *Annual General Reports*, by C. Le Neve Foster, and *Statisque de l'Industrie Minérale.* Additional products in 1896: Gypsum, 4,700 metric tons; marble, 1,000 metric tons; phosphate of lime, 1,000 metric tons; building stone (dressed), 18,000 cu. meters; stone (broken), 135,000 cu. meters. In 1899, 70,000 tons phosphate rock, valued at $168,000; in 1900, 178,000 tons valued at $781,000. (*b*) Not reported. (*c*) Value corresponding to only 10,600 tons.

GERMANY.

THE mineral statistics of the German Empire, together with those of Baden, Bavaria, Prussia and Saxony, are summarized in the subjoined tables:

MINERAL PRODUCTION OF GERMANY. (*a*) (*b*) (IN METRIC TONS AND DOLLARS: 4 marks = $1.)

Year.	Alum.		Aluminum Sulphate.		Antimony and Manganese.		Antimony Ore.		Arsenic Ore.		Arsenical Products.	
1896.....	3,430	$98,250	34,370	$595,000	1,326	$156,111	*Nil.*	.....	3,691	$46,960	2,637	$221,397
1897.....	2,995	73,838	37,053	613,684	1,665	210,744	*Nil.*	.....	3,777	56,021	2,989	270,949
1898.....	4,069	91,086	35,366	514,962	2,711	302,892	*Nil.*	.....	3,540	52,414	2,679	253,628
1899.....	3,358	73,500	37,693	568,250	3,149	434,000	*Nil.*	.....	3,834	61,250	2,423	267,250
1900.....	4,355	93,750	44,372	675,000	3,338	473,750	*Nil.*	.....	4,380	79,000	2,414	263,250
1901.....	(*e*)	.....	(*e*)	.....	(*e*)	.....	(*e*)	.....	(*e*)	.....	(*e*)	.....

Year.	Asphaltum.		Boracite.		Cadmium—Kg.		Coal.		Cobalt, Nickel and Bismuth Ores.		Copper, Ingot.	
1896....	61,552	$113,848	184	10,620	10,000	$19,117	85,690,223	$148,244,000	4,087	$129,688	29,319	$7,398,397
1897....	61,645	94,634	198	10,222	15,531	44,157	91,054,982	162,234,685	3,355	139,777	29,408	7,545,376
1898....	67,649	104,084	230	10,746	14,943	31,162	96,279,902	177,564,243	3,157	138,545	30,695	8,182,102
1899....	74,770	130,250	183	8,750	13,608	21,250	101,639,753	197,362,000	1,270	133,500	34,633	12,519,000
1900....	89,685	160,000	232	11,000	13,583	20,500	109,271,726	241,498,250	4,495	168,000	30,998	11,738,500
1901....	90,198	.....	(*e*)	.....	(*e*)	.....	108,417,029	.....	10,479	.....	31,376	.....

Year.	Copper Matte and Black Copper.		Copper Ore.		Gold—Kg.		Graphite.		Iron Ore.	
1896.....	508	$39,083	717,306	$4,299,362	2,497	$1,728,998	5,248	$72,108	14,162,315	$12,349,650
1897.....	315	14,380	700,619	4,752,552	2,781	1,934,371	3,961	66,126	15,465,979	15,021,922
1898.....	62	2,170	702,781	4,921,152	2,847	1,978,353	4,598	97,916	15,893,246	15,202,159
1899.....	95	4,000	733,619	5,217,000	2,605	1,814,750	5,196	120,250	17,999,635	17,542,500
1900.....	4,207	614,500	747,775	5,956,000	3,054	2,130,750	9,248	136,500	18,964,367	19,407,000
1901.....	305	.....	777,389	.....	(*e*)	.....	(*e*)	.....	16,570,258	.....

Year.	Iron, Pig.		Lead.		Lead Ore.		Lignite.		Litharge.		Magnesium Sulphate. (*f*)	
1896..	6,296,272	$73,930,749	118,792	$6,258,097	157,504	$3,249,000	26,797,880	$15,233,273	3,930	$295,698	2,350	$5,250
1897..	6,864,405	87,345,441	118,881	7,160,138	150,179	3,253,884	29,419,503	16,562,642	3,341	218,699	2,601	5,637
1898..	7,215,927	93,575,641	132,742	8,555,606	151,601	3,412,128	31,643,498	18,339,809	3,857	265,496	2,444	5,277
1899..	7,160,203	102,820,750	129,225	9,315,000	144,370	3,528,000	34,204,666	17,458,970	3,561	270,750	2,082	4,250
1900..	7,549,655	122,989,750	121,513	10,174,250	148,230	4,516,000	40,279,332	24,436,500	3,087	266,750	1,750	3,750
1901..	7,885,204	.....	123,098	.....	153,340	.....	44,211,902	.....	4,101	.....	(*e*)	.....

Year.	Manganese Ore		Magnesium Chloride (From Solution.)		Magnesium Sulphate (From Solution.)		Mineral Paints.		Nickel & Various By-Products. (*c*)		Petroleum.	
1896....	45,062	$120,155	17,525	$57,386	27,161	$107,835	2,668	$75,313	1,391	$1,365,330	20,395	$297,128
1897....	46,427	115,356	18,014	64,294	35,072	155,585	3,119	84,071	1,464	1,492,337	23,303	349,111
1898....	43,354	111,786	19,919	96,973	30,295	122,667	3,031	91,153	1,691	1,465,254	25,789	394,552
1899....	61,329	177,750	21,369	81,250	39,540	148,500	3,351	97,000	1,747	1,550,000	27,027	394,500
1900....	59,208	183,500	19,397	76,250	48,591	158,000	3,311	91,750	1,989	2,000,000	50,375	981,500
1901....	56,691	.....	(*e*)	.....	(*e*)	.....	(*e*)	.....	(*e*)	.....	44,095	.....

Year.	Potassium Salts.									
	Chloride.		Kainite.		Potassium and Magnesium Sulphate.		Sulphate.		Unspecified.	
1896....	174,515	$5,718,559	856,290	$2,989,736	4,623	$85,977	19,682	$813,381	902,707	$2,964,750
1897....	168,001	5,764,423	992,389	3,486,007	7,812	149,079	13,774	565,720	953,798	3,030,143
1898....	191,347	6,380,220	1,108,643	3,835,856	13,982	259,485	18,853	768,397	1,105,212	3,576,628
1899....	207,506	6,801,250	1,108,159	3,838,250	9,765	195,000	26,103	1,027,500	1,384,972	4,202,000
1900....	271,512	8,798,750	1,178,527	4,184,000	15,368	290,500	23,853	1,249,250	1,874,946	5,643,750
1901....	282,750	.....	1,500,748	.....	(*e*)	.....	27,304	.....	2,096,326	.....

Year.	Pyrites.		Salt.		Salt, Rock.		Silver and Gold Ore.		Silver—Kg.	
1896....	194,950	$231,579	547,486	$3,661,034	755,883	$755,888	18,487	$596,604	428,429	$9,718,000
1897....	133,302	241,117	543,272	3,034,128	763,412	804,298	9,708	363,271	448,068	9,095,366
1898....	136,849	242,596	565,683	3,116,087	804,658	838,656	12,413	336,657	480,578	9,599,163
1899....	144,623	259,250	571,058	3,021,750	861,123	957,000	13,506	479,750	467,590	9,458,000
1900....	169,447	303,750	587,464	3,567,000	926,563	1,060,500	12,537	514,500	415,785	8,663,250
1901....	157,420	.....	578,761	.....	985,919	.....	11,576	.....	(e)	.....

Year.	Sodium Salts. (Glauber Salt.)		Sulphur.		Sulphuric Acid.		Sulphates. (d)							
							Copper.		Iron.		Zinc.		Copper and Iron Mixed.	
1896....	71,958	$448,915	2,263	$47,181	590,888	$3,781,092	6,046	$466,478	9,788	$39,072	4,811	$67,171	165	$6,218
1897....	68,822	434,198	2,317	48,357	623,180	3,739,472	5,549	470,016	10,351	44,684	5,488	77,495	266	10,543
1898....	69,111	452,509	1,954	43,167	664,865	4,065,784	4,852	356,540	10,422	42,707	6,104	91,152	176	6,991
1899....	79,002	504,000	1,663	36,000	832,666	5,737,000	5,142	460,750	10,931	38,750	7,117	107,000	212	9,000
1900....	90,468	663,750	1,445	31,000	829,376	5,885,000	5,076	587,000	10,747	41,000	6,026	80,250	166	7,000
1901....	76,065	.....	(e)	.....	(e)	.....	(e)	.....	(e)	.....	(e)	.....	(e)	.....

Year.	Tin		Tin Ore.		Uranium and Wolfram Ores.		Zinc.		Zinc Ore.		Vitriol and Alum Ores. Unspecified.	
1896....	898	$135,734	88	$5,881	41	$7,081	153,100	$11,777,005	729,942	$4,255,473	369	$512
1897....	929	287,820	55	5,962	38	8,367	150,739	12,619,131	663,850	4,220,339	225	338
1898....	903	372,252	51	3,550	50	11,527	154,181	14,708,459	641,706	5,511,819	188	282
1899....	1,481	870,750	72	10,000	50	13,000	153,155	18,737,750	664,536	8,853,000	533	750
1900....	2,081	1,322,750	81	11,250	43	11,250	155,790	15,516,750	639,215	6,438,250	350	500
1901....	(e)	.....	(e)	.....	(e)	.....	166,233	.....	647,496	.....	(e)	.....

(a) Including Luxemburg. (b) From *Vierteljahrs- und Monats-hefte zur Statistik des Deutschen Reichs.* (c) Including metallic bismuth, cobalt products, and uranium salts. (d) There was also produced nickel sulphate and tin chloride as follows: 1896, 176 tons, $42,966; 1897, 209 tons, $51,333. (e) Kieserite, glauberite, etc.

MINERAL IMPORTS OF GERMANY. (a) (IN METRIC TONS; unit of value, $1,000; $1 = 4 marks.)

Year.	Alabaster and Marble, Crude.		Aluminum, Nickel Wares, etc.		Ammonium Sulphate.		Cement.		Clay Products.					
									Brick and Roofing Tile.		Porcelain.		Kaolin, Feldspar and Fire Clay.	
1896..	26,655	$800	335	$350	32,061	$1,450	32,394	$275	140,333	$475	806	$325	192,807	$1,675
1897..	29,633	900	417	425	33,113	1,325	42,364	350	151,455	575	812	350	207,155	2,050
1898..	(c)	....	459	475	30,254	1,275	53,519	325	b186,183	600	788	325	208,186	2,100
1899..	(c)	....	495	550	28,868	1,450	63,388	306	b176,704	675	704	300	235,233	2,500
1900..	(c)	....	483	546	23,105	1,213	79,303	706	b180,094	721	765	313	265,289	2,882

Year.	Coal.		Coal. (Lignite.)		Coke.		Copper.			
							Bars and Sheets.		Crude.	
1896.....	5,476,753	$15,275	7,637,503	$11,275	393,881	$1,625	401	$125	56,115	$13,675
1897.....	6,072,039	16,625	8,111,076	12,775	435,161	1,950	400	125	67,573	17,025
1898.....	5,820,332	17,250	8,450,149	13,250	332,579	1,675	450	150	78,291	19,700
1899.....	6,220,489	21,350	8,616,751	15,075	462,577	2,600	610	250	70,091	26,000
1900.....	7,384,049	33,720	7,960,313	16,916	512,690	3,226	906	381	83,508	31,692

Year.	Copper—*Con.*		Copper and Brass Manufactures.						Glass Manufactures, All Kinds.		Gold.			
	Scrap and Coin.		Fine.		Wire.		Cartridge Cases, Coarse Wares, etc.				Bullion. Kg.		Coin. Kg.	
1896.....	3,170	$700	797	$675	127	$50	582	$275	2,823	$1,050	45,417	$31,600	37,507	$23,475
1897.....	4,199	950	846	700	80	25	612	300	2,057	475	34,991	24,325	22,914	14,350
1898.....	4,720	1,150	881	800	55	25	546	275	2,408	525	62,937	43,775	60,355	37,750
1899.....	4,992	1,750	962	925	79	25	565	350	2,337	517	51,539	35,950	50,709	31,875
1900.....	4,608	1,674	1,007	989	76	31	504	305	2,746	558	37,094	25,873	54,859	34,438

Year.	Gold and Silver. Scrap, Pagament. Kg.		Gold and Silver. Manufactures. Kg.		Gold, Silver, and Platinum Ores.		Graphite.		Iodine.		Iron. Angle.		Iron. Blooms, Bars, and Ingots.		Iron. Castings.	
1896..	39,395	$3,700	34,310	$825	6,024	$3,950	13,718	$450	94	$625	176	(c)	1,054	$25	19,600	$2,450
1897..	36,664	3,075	35,160	750	8,927	4,475	17,366	600	164	950	1,081	$29	1,088	25	24,627	2,950
1898..	54,793	4,525	31,549	700	7,481	2,650	20,269	950	216	1,275	207	6	1,553	44	39,371	3,895
1899..	44,463	3,725	34,775	875	7,597	2,725	23,400	1,075	191	1,125	898	25	1,341	47	45,853	4,925
1900..	45,774	3,948	33,259	1,603	9,153	3,364	22,495	955	236	1,358	827	31	2,778	116	45,348	5,702

Year.	Iron.—*Continued.* Ore.		Pig.		Rails.		Scrap.		Wire.		Wrought in Bars.		All Other Manufactures.		Lead, Pig and Scrap.	
1896..	2,586,706	$8,700	322,502	$4,000	140	(c)	14,679	$175	6,398	$450	23,770	$875	12,933	$1,650	33,016	$1,925
1897..	3,185,644	11,675	423,127	5,375	774	$25	37,957	450	5,609	375	29,467	1,225	18,135	1,975	35,092	2,350
1898..	3,516,577	13,625	384,561	4,900	207	7	23,328	300	7,166	475	26,014	1,100	20,158	1,900	47,497	3,250
1899..	4,165,372	17,550	612,652	9,975	1,319	50	63,141	1,050	8,582	675	37,179	1,800	31,222	2,863	55,635	4,550
1900..	4,107,840	18,796	726,712	14,604	343	10	100,383	2,152	8,711	693	37,809	2,098	28,913	3,498	70,252	6,273

Year.	Lead and Copper Ores.		Lead, White.		Manganese Ore.		Nickel.		Oxide. (Potash.)		Petroleum. Illuminating Oil.		Petroleum. Lubricating Oil.	
1896..	88,341	$2,025	579	$50	33,870	$750	951	$600	1,430	$100	853,642	$14,950	81,256	$3,425
1897..	90,114	3,300	696	54	86,911	925	1,390	875	1,734	125	946,344	12,300	88,957	3,250
1898..	64,727	2,800	822	66	130,711	1,325	1,467	850	1,486	100	954,646	16,200	97,028	3,750
1899..	65,821	3,675	703	63	196,825	2,275	1,391	825	1,737	125	963,943	19,775	106,624	4,400
1900..	62,268	4,531	698	66	204,420	2,461	1,712	1,220	1,522	122	989,361	21,000	124,505	5,608

Year.	Phosphate Rock.		Potassium Salts. Chloride.		Potassium Salts. Cyanide.		Potassium Salts. Iodide.		Potassium Salts. Nitrate.		Potassium Salts. Sulphate.		Pyrites.	
1896..	216,950	$2,700	1,058	$50	8	(c)	29	$150	1,380	$125	703	$25	343,852	$1,650
1897..	289,234	3,625	715	25	7	(c)	18	25	2,889	275	912	25	356,869	1,900
1898..	270,988	2,700	422	15	2	(c)	16	50	1,895	175	999	25	376,817	2,175
1899..	407,457	4,325	443	16	8	(c)	9	25	1,785	163	533	16	437,732	3,750
1900..	320,138	3,682	484	17	.....	(c)	10	55	2,047	195	856	26	457,679	3,961

Year.	Salt.		Silica, Sand, Marl, tc.		Silver. Bullion—Kg.		Silver. Coin—Kg.		Slag and Slag Wool.		Slag, Thomas Slag, Ground.		Slate.	
1896..	22,908	$100	253,905	$250	127,753	$2,900	20,785	$425	680,251	$2,525	83,765	$525	53,583	$1,050
1897..	(c)	.....	228,241	225	147,084	2,975	20,331	375	670,224	2,575	110,216	575	48,380	1,075
1898..	(c)	.....	239,708	250	104,770	2,075	40,182	725	685,118	2,625	88,374	500	57,571	1,400
1899..	(c)	.....	279,089	275	89,930	1,825	(c)	....	892,764	3,250	68,305	475	68,309	1,550
1900..	(c)	.....	386,028	388	167,432	3,489	(c)	....	974,947	4,694	103,481	627	54,646	1,328

Year.	Soda, Calcined.		Soda. Nitrate. (Chile Saltpeter.)		Stassfurt Salts.		Stone. Rough or Simply Hewn.		Stone. Limestone, Lime.		Stone. Grindstones, Polishing and Whetstones.		Sulphur.	
1896..	1,295	$25	449,028	$16,850	143	(c)	767,908	$3,850	216,641	$1,200	2,869	$275	21,864	$500
1897..	916	25	465,493	16,875	6	(c)	853,825	4,275	235,715	1,300	1,820	114	25,305	625
1898..	524	12	425,054	15,325	17	(c)	931,826	4,275	242,397	1,325	1,967	187	30,269	750
1899..	515	12	526,944	19,425	192	$1	1,021,755	5,200	229,912	805	2,182	208	(c)	.....
1900..	373	9	484,544	19,382	130	1	1,072,433	6,479	272,824	1,021	2,236	209	.....	.....

Year.	Tin. Crude.		Tin. Manufactures		Zinc. Crude.		Zinc. Drawn and Rolled.		Zinc. Manufactures		Zinc. Ore.		Zinc-White, Zinc-Gray, and Lithophone.	
1896..	13,798	$4,275	75	$75	16,343	$1,350	180	$25	139	$75	21,493	$325	2,899	$250
1897..	12,395	3,875	75	75	19,734	1,850	130	12	146	75	24,735	400	3,532	325
1898..	14,623	5,300	82	100	24,116	2,425	53	6	128	75	48,050	900	3,653	375
1899..	12 253	7,575	88	125	23,691	2,925	95	12	126	75	57,880	1,450	4,226	475
1900..	12,454	8,375	115	160	24,263	2,374	145	16	132	83	68,982	1,456	4,884	512

MINERAL EXPORTS OF GERMANY. (*a*) (IN METRIC TONS; unit of value, $1,000; $1 = 4 marks.)

Year.	Alabaster and Marble, Crude.		Aluminum, Nickel Wares, etc.		Ammonium Sulphate.		Cement.		Clay Products. Roofing Tile, and Building Stone.		Clay Products. Porcelain.		Clay Products. Kaolin, Feldspar and Fire Clay.	
1896	2,174	$100	1,977	$2,050	2,201	$100	478,340	$4,100	287,811	$1,775	21,634	$8,975	125,674	$1,250
1897	2,727	75	1,899	1,950	2,623	100	524,557	4,500	283,229	1,550	21,687	8,775	121,535	475
1898	(*c*)	.....	2,045	2,150	4,063	175	551,744	5,000	*b*265,110	1,000	21,644	8,425	129,063	650
1899	(*c*)	.....	2,312	2,575	1,553	75	580,255	5,175	*b*224,819	850	23,110	9,275	143,406	725
1900	(*c*)	.....	2,398	2,680	2,431	128	600,386	6,360	*b*182,340	729	26,642	10,738	159,855	941

Year.	Coal.		Coal, Lignite.		Coke.		Copper. Crude.		Copper. Bars and Sheets, Unplated.		Copper. Scrap and Coin.	
1896.....	11,598,757	$30,475	15,708	$25	2,216,395	$9,000	5,996	$1,500	5,406	$1,700	2,968	$650
1897.....	12,389,907	33,375	19,112	25	2,161,896	9,150	7,183	1,825	5,718	1,825	2,164	525
1898.....	13,999,223	39,925	22,155	25	2,133,179	10,200	6,972	1,875	5,969	1,800	3,636	900
1899.....	13,943,174	45,050	20,925	25	2,137,985	11,500	7,061	2,600	4,871	2,125	5,217	1,800
1900.....	15,275,805	54,235	52,795	106	2,229,188	13,942	5,505	2,091	5,273	2,338	5,455	1,999

Year.	Copper and Brass Manufactures. Fine.		Copper and Brass Manufactures. Wire.		Copper and Brass Manufactures. Cartridge Cases, Coarse Wares, etc.		Glass Manufactures, All Kinds.		Gold. Bullion. Kg.		Gold. Coin. Kg.		Gold and Silver Manufactures. Kg.	
1896..	5,961	$4,950	5,910	$1,950	6,806	$4,375	108,802	$9,175	34,747	$24,225	40,095	$25,150	96,709	$5,525
1897..	5,583	4,625	6,176	2,025	5,409	3,350	105,702	9,050	32,312	22,525	11,385	7,150	101,429	9,975
1898..	6,472	5,475	5,930	2,025	6,278	3,775	102,615	7,757	4,851	3,375	82,992	52,050	98,939	10,275
1899..	7,561	6,975	7,579	3,375	5,846	3,950	111,037	8,450	4,850	3,388	48,594	30,550	107,021	12,175
1900..	8,888	8,295	9,605	4,308	4,906	3,334	124,501	9,266	5,587	3,902	39,072	24,563	111,117	18,371

Year.	Gold, Silver, and Platinum Ores.		Graphite.		Iodine.		Iron and Steel. Angle.		Iron and Steel. Blooms, Bars and Ingots.		Iron and Steel. Cast, Crude.		Iron and Steel. Man'factures, All Other.		Iron and Steel. Iron Ore.	
1896	14	$25	2,364	$125	26	$175	178,887	$4,675	49,529	$1,125	153,652	$24,325	309,882	$23,200	2,642,294	$1,975
1897	53	25	2,422	125	26	150	169,287	4,400	39,792	900	170,084	26,725	296,949	22,400	3,230,391	2,400
1898	19	75	2,936	175	26	150	204,705	5,400	34,964	800	193,039	30,600	312,948	22,875	2,933,734	2,150
1899	5	10	2,703	175	26	150	221,165	7,200	23,438	639	205,935	36,075	332,670	30,043	3,119,878	2,650
1900	21	5	2,068	78	29	177	215,641	7,709	33,627	1,010	196,759	38,723	374,571	39,969	3,247,888	2,992

Year.	Iron and Steel.—*Continued.* Iron, Pig.		Rails.		Scrap.		Wire.		Wrought, in Bars.		Lead and Copper Ores.		Lead, Pig and Scrap.		Lead, White.	
1896	140,449	$1,925	129,413	$3,100	58,466	$750	207,116	$6,875	259,461	$7,175	31,675	$200	24,828	$1,425	16,350	$1,275
1897	90,885	1,250	113,473	2,850	38,102	550	198,909	6,625	246,772	7,075	26,317	225	24,075	1,525	14,786	1,225
1898	187,375	2,525	123,839	3,250	85,095	1,800	188,713	6,625	263,698	7,640	24,163	225	24,867	1,625	16,473	1,400
1899	182,091	3,025	109,818	3,300	53,103	1,025	154,332	6,300	193,933	6,775	35,359	1,525	24,491	1,850	16,360	1,625
1900	129,409	2,561	155,656	4,895	61,096	1,250	169,839	7,465	172,533	6,358	26,995	718	18,895	1,627	15,126	1,586

Year.	Manganese Ore.		Nickel.		Oxide. (Potash.)		Phosphate Rock.		Potassium Salts. Chloride.		Potassium Salts. Cyanide.		Potassium Salts. Iodide.		Potassium Salts. Nitrate.		Potassium Salts. Sulphate.	
1896..	7,178	$150	143	$100	12,673	$1,050	5,548	$100	85,862	$3,075	55	$125	142	$950	11,323	$1,750	16,019	$575
1897..	8,615	100	169	100	13,100	775	4,000	75	80,389	2,850	1,066	(*c*)	124	775	8,986	850	20,971	675
1898..	4,810	75	203	125	13,456	800	5,100	75	96,236	3,375	1,907	975	135	850	10,909	1,000	27,105	850
1899..	7,040	100	295	175	11,917	900	2,504	50	101,045	3,650	1,645	825	145	900	15,146	1,375	32,845	1,150
1900..	2,454	45	268	235	15,761	1,419	1,123	20	114,469	4,078	(*c*)	....	138	759	14,744	1,401	38,125	1,330

Year.	Pyrites.		Salt.		Silica, Sand, Marl, etc.		Silver. Crude and in Bars.		Silver. Coin.		Slag and Slag Wool.		Slag, Thomas Slag, Ground.	
1896..	16,833	$75	214,060	$625	267,173	$225	305,826	$6,975	31,648	$650	17,214	$50	134,257	$875
1897..	15,387	75	(*e*)	.....	652,248	575	371,086	7,550	27,687	525	27,723	98	160,336	1,225
1898..	19,220	100	(*c*)	.....	910,354	800	348,733	6,950	46,932	975	29,931	105	187,598	1,400
1899..	16,985	75	(*c*)	.....	872,292	775	294,039	6,000	(*c*)	.....	25,565	106	199,392	1,550
1900..	24,936	141	(*c*)	.....	822,840	926	284,853	5,971	(*c*)	.....	24,936	141	174,563	1,407

Year.	Slate.		Soda. Calcined.		Sodium Nitrate. (Chile Saltpeter.)		Stassfurt Salts.		Stone. Crude or Simply Hewn.		Stone. Limestone, Lime.		Stone. Grindstones, Polishing and Whetstones.	
1896..	5,796	$100	41,106	$925	9,078	$400	285,023	$1,575	620,394	$3,100	77,641	$350	11,914	$900
1897..	4,948	100	45,672	1,025	11,364	475	337,577	1,700	545,723	2,725	77,905	350	7,390	370
1898..	4,434	100	37,106	825	12,884	525	370,829	1,750	556,561	3,225	84,892	375	7,263	363
1899..	3,034	68	40,566	975	13,910	575	367,828	1,975	597,286	4,275	84,915	381	8,138	508
1900..	3,123	78	44,376	1,108	14,159	602	468,277	2,868	675,605	6,453	78,758	384	8,795	880

Year.	Tin. Crude.		Tin. Manufactures		Zinc. Ore.		Zinc. Crude.		Zinc. Drawn and Rolled.		Zinc. Manufactures		Zinc-White, Zinc-Gray, and Lithophone.	
1896..	868	$275	1,010	$850	37,959	$575	58,082	$4,750	16,227	$1,500	1,206	$825	16,969	$1,325
1897..	861	275	967	800	30,047	500	51,341	4,400	17,453	1,650	1,163	800	17,631	1,325
1898..	874	325	1,119	1,000	30,408	575	51,324	5,175	14,477	1,575	1,205	850	18,674	1,775
1899..	1,121	700	1,218	1,375	25,192	575	46,334	5,675	18,281	2,425	1,561	1,125	19,489	2,175
1900..	1,626	1,102	1,315	1,496	34,941	655	51,899	5,214	16,709	1,817	1,731	1,259	20,729	2,093

(*a*) From *Statistisches Jahrbuch für das Deutsche Reich.* (*b*) In 1898, 1899 and 1900, represents unglazed tile and brick only. ((*c*) Not reported.

MINERAL IMPORTS AND EXPORTS OF GERMANY FOR THE YEAR 1901. (IN METRIC TONS.)

The following figures are taken from *Chemiker Zeitung*, of Feb. 13, 1902, and while probably from official sources, are subject to correction.

Substances.	Imports.	Exports.
Alum, and aluminate of sodium and alumina, including hydrate.	147	31,171
Aluminum	1,090	282
Ammonium carbonate	2,516	3,196
Ammonium sulphate	44,408	9,842
Ammoniacal liquor	13,765	15,399
Antimony	1,494	76
Antimony and arsenic ore	1,098	283
Arsenic	.....	28
Arsenic, white	377	901
Arsenical compounds	43	734
Asbestos and asbestic mastic	5,514	638
Asphalt, pitch, and wood cement	62,299	39,671
Barium chloride	1,768	3,353
Barium salts, N. E. S.	43	3,451
Baryta-white	0·7	2,765
Barytes	3,135	67,179
Borax and boric acid	2,537	2,563
Brass and tombac	1,709	5,013
Bromide of potash and other bromine preparations	1	249
Bromine	0·1	228
Calcium chloride	195	888
Carbon bisulphide	50	178
Carbonic acid	14	3,718
Cement	87,262	560,612
Chloride of lime	138	32,705
Chloride of magnesium	28	16,102
Chrome alum	9	1,299
Chrome ore	18,222	581
Coal	6,297,389	15,266,267
Coal-tar oil, light	7,723	2,260
Coal-tar oil, heavy	9,269	5,989
Cobalt and nickel ore	12,186	96
Coke	400,197	2,096,931
Copper, crude	58,620	5,091
Copper, in bars and sheets	151	1,870
Copper alloys, in bars, sheets, etc.	574	3,082
Cinnabar	9	210
Cryolite and bauxite	25,361	503
Explosives	50	3,497
Fluorspar	515	12,894
Gold, silver, and platinum ores	8,764	6
Gold preparations and salts	0·1	6
Graphite, crude	17,374	1,667
Gunpowder	49	1,869
Gypsum	7,622	40,090
Hydrochloric acid	3,053	12,143
Iodine	266	27
Iron, crude, all kinds	298,866	303,846
Iron, wrought, in bars	22,499	329,513
Iron alum and iron mordant	491	895
Iron ores	4,370,022	2,389,269
Iron oxide, red	2,259	1,549
Kaolin, feldspar, and refractory clay	249,180	128,174
Lead and copper ores	104,809	28,170
Lead	52,886	20,820
Lead, white	423	16,966
Lignite	8,108,943	21,718
Litharge	244	4,896
Magnesium, artificial carbonate	88	143
Magnesium, natural carbonate	8,897	2,289
Manganese ore	222,010	5,584
Manganese preparations	391	812
Mineral oil for use in the arts	4,037	.....
Nickel	1,947	390
Nitric acid	1,454	1,521
Ozokerite, crude	1,981	973
Ozokerite, refined	87	1,720
Petroleum, crude	10,103	0·2
Petroleum, distilled	5,566	3,972
Petroleum, refined	911,795	702
Phosphorus	318	149
Pitch, except asphalt	59,488	4,613
Potash	1,758	15,567
Potash, caustic	165	14,892
Potassium and sodium chlorate	1,970	716
Potassium chloride	462	118,959
Potassium chromate	490	701
Potassium cyanide	0·9	4,443
Potassium iodide and other iodine preparations	5	144
Potassium sulphate	680	37,216
Quicksilver	651	27
Salt	93,901	286,494
Saltpeter, Chile	529,568	13,481
Saltpeter, potassium	1,529	13,439
Soda, calcined	178	45,967
Soda, caustic	265	4,926
Soda, crude and crystallized	38	1,382
Soda chromate	197	2,090
Soda, double carbonate	120	1,086
Sodium and potassium sulphide	188	3,710
Stone, refractory, from clay	26,886	97,226
Strontia minerals	19,739	384
Strontia preparations	409	1,022
Sulphur	32,750	621
Superphosphate	107,365	79,190
Thomas slag, ground	87,152	202,737
Tin	12,910	1,663
Tin salts	60	394
Ultramarine	85	4,045
Vitriol, all kinds	1,714	6,389
Waterglass	242	5,228
Witherite	2,629	347
Zinc, ingot	21,250	54,490
Zinc ores	75,733	41,002
Zinc, sheet	306	16,517
Zinc white, zinc gray, and zinc sulphate	3,673	24,200

MINERAL PRODUCTION OF BADEN. (*a*) (IN METRIC TONS AND DOLLARS; 4 marks = $1.)

Year.	Alumina Sulphate.		Barytes.		Coal.		Fire Clay.		Gypsum.		Iron. Cast, Foundry.	
1896.....	1,824	$27,133	130	$97	4,001	$11,003	6,819	$4,267	32,801	$24,651	31,356	$1,730,776
1897.....	1,824	27,134	400	900	4,752	11,880	11,450	6,654	40,702	26,972	36,235	1,876,262
1898.....	2,051	30,505	1,100	825	4,133	10,333	5,112	3,529	28,037	16,137	39,988	1,876,262
1899.....	2,153	29,610	2,430	2,126	4,700	13,000	4,775	3,475	29,419	18,371	53,608	2,769,292
1900.....	2,286	33,725	2,970	2,745	4,930	15,406	3,096	2,650	26,381	15,429	50,102	2,745,068

Year.	Iron.—*Continued.* Ingot.		Wrought.		Lead and Copper Ores.		Limestone. (*d*)		Manganese Ore.		Salt.	
1896.....	3,418	$143,371	1,118	$51,954	(*b*)	$103	116,913	$16,496	130	$325	29,227	$136,993
1897.....	3,875	147,718	1,167	58,401	(*b*)	.....	137,670	19,502	(*b*)	.....	31,445	136,993
1898.....	3,875	147,718	1,167	58,401	(*b*)	.....	164,979	26,104	(*b*)	.....	31,445	136,993
1899.....	3,830	171,863	1,402	63,117	(*b*)	.....	201,015	31,674	(*b*)	.....	31,197	116,797
1900.....	3,532	184,999	1,364	85,217	67	3,308	221,097	36,312	(*b*)	.....	32,299	192,204

Year.	Sand Quartz.		Stone Porphyry.		Sulphuric Acid.		Tripoli.		Zinc Ore.	
1896.....	1,198	$602	(*b*)	.....	14,226	$78,243	9·0	$1,125	(*b*)	.....
1897.....	1,648	1,172	28,000	$7,000	13,365	73,507	9·0	1,800	(*b*)	.....
1898.....	1,694	910	7,650	1,912	13,365	73,507	6·0	575	(*b*)	.....
1899.....	1,461	798	22,261	5,565	13,660	68,300	11·8	1,498	357	$6,245
1900.....	2,668	1,212	23,421	5,855	15,938	92,840	9·4	1,239	3,004	39,898

(*a*) Reported to THE MINERAL INDUSTRY by the *Grossherzogliche Badische Domänendirektion*, Carlsruhe.
(*b*) Not reported. (*d*) Including cement stone and bituminous shale.

MINERAL PRODUCTION OF BAVARIA. (*a*) (IN METRIC TONS; 4 marks = $1.)

Year.	Barytes.		Clay. Fire Clay.		Clay. Kaolin.		Coal.		Coal, (Lignite).	
1896.....	3,397	$3,404	110,174	$251,899	19,080	$26,268	900,080	$2,129,069	35,934	$33,581
1897.....	3,365	2,906	144,425	300,495	24,086	38,345	917,022	2,267,086	39,043	24,913
1898.....	4,339	6,465	282,994	671,465	29,196	35,426	964,611	2,449,264	38,663	32,842
1899.....	6,214	8,642	271,792	505,033	25,822	23,573	1,004,421	2,648,276	35,736	33,228
1900.....	10,515	15,067	187,501	463,689	58,795	68,274	1,185,296	3,849,126	39,165	36,117

Year.	Copperas and other Sulphate.		Emery.		Feldspar.		Fluorspar.		Graphite.		Gypsum.		Iron. Ore.	
1896..	601	$32,209	249	$2,527	1,315	$3,145	5,218	$8,280	5,248	$72,108	28,709	$15,334	161,279	$164,262
1897..	981	38,540	217	2,307	1,689	4,678	4,904	5,744	3,861	66,126	26,153	13,609	172,699	173,809
1898..	886	42,663	280	2,156	1,049	8,052	4,440	5,210	4,593	97,916	25,688	13,166	171,987	178,130
1899..	900	44,236	399	4,180	287	1,085	3,631	5,866	5,196	120,292	29,727	20,652	181,981	194,348
1900..	916	45,160	414	4,430	460	1,723	7,456	10,568	9,248	136,620	35,484	17,199	178,441	199,992

Year.	Iron.—*Continued.* Bar.		Cast, 1st Fusion.		Cast, 2d Fusion.		Pig.		Wire.	
1896.....	53,573	$1,587,388	114	$3,993	71,006	$3,378,247	79,621	$907,306	243	$6,232
1897.....	58,200	1,884,224	138	4,829	78,008	3,735,979	83,418	968,932	252	6,895
1898.....	58,342	1,864,479	97	3,566	84,227	4,067,760	84,144	1,005,125	323	9,628
1899.....	61,415	2,102,492	(*b*)	.....	92,459	4,623,992	93,821	1,019,184	111	3,372
1900.....	49,727	2,093,750	29	1,000	89,692	4,728,500	82,327	1,114,250	221	6,780

Year.	Iron.—*Continued.* Steel.		Manganese Ore.		Marl. (For Cement.)		Mineral Paints.		Pyrites.		Rock Salt.	
1896.....	101,954	$2,497,814	70	$35	94,481	$99,929	8,667	$26,496	1,997	$14,930	708	$4,572
1897.....	115,530	2,851,035	130	197	97,831	90,591	8,673	25,872	2,211	7,080	1,161	5,582
1898.....	120,623	3,284,299	(*b*)	.....	110,757	52,374	8,748	31,737	2,304	7,285	736	4,036
1899.....	134,007	3,898,125	(*b*)	.....	220,716	79,917	9,287	33,351	2,516	7,689	802	6,610
1900.....	135,411	4,356,116	(*b*)	.....	180,032	74,054	11,507	25,078	2,120	6,342	1,298	6,562

Year.	Salt, Brine.		Silica (Quartz Sand).		Slate.		Soapstone.		Sodium Sulphate.		Stone. Flagstones.	
1896	40,400	$438,379	29,868	$8,441	1,565	$14,252	3,051	$52,458	668	$3,067	20,559	$96,620
1897	41,533	388,029	31,678	8,812	1,496	14,001	2,464	35,360	2,818	12,749	14,647	57,343
1898	39,717	469,629	45,907	17,444	3,956	24,039	1,912	29,193	2,332	14,185	16,720	81,692
1899	41,207	422,641	89,922	17,000	2,066	22,915	2,197	33,860	1,570	8,625	20,195	95,902
1900	44,431	482,550	42,671	20,046	1,904	21,457	1,977	32,240	1,821	10,765	16,208	76,898

Year.	Stone—*Continued.* Granite and other Massive Rocks.		Limestone.		Lithographic.		Sandstone.		Whetstone.		Sulphuric Acid.	
1896	658,581	$856,753	238,434	$74,982	10,868	$163,020	235,518	$321,591	88	$3,740	7,064	$61,214
1897	663,749	711,029	224,550	76,385	13,941	217,821	242,112	315,117	95	3,800	7,041	63,709
1898	678,171	790,124	214,309	78,897	12,029	180,435	296,139	418,580	85	1,675	103,385	1,030,499
1899	490,712	729,632	267,180	93,891	11,962	239,240	315,786	417,917	81	1,125	123,278	1,217,000
1900	523,279	810,330	297,635	111,460	16,030	328,100	314,154	378,795	25	500	123,910	1,252,500

(*a*) From the *Uebersicht der Production des Bergwerks-, Hütten-, und Salinen-Betriebes in dem Bayerischen Staate.* (*b*) Not reported.

MINERAL PRODUCTION OF PRUSSIA. (*a*) (METRIC TONS; 4 marks — $1.)

Year.	Alum Shale		Antimony and Alloys.		Arsenic Products.		Arsenic Ore		Asphalt.	
1896	154	$231	1,239	$113,886	1,750	$130,539	3,247	$41,196	16,204	$43,715
1897	129	193	1,552	152,744	1,924	143,775	3,377	50,655	11,466	18,706
1898	107	161	2,612	251,642	1,624	121,818	3,298	49,470	12,822	20,402
1899	145	217	3,003	352,565	1,469	128,543	3,265	52,406	16,458	41,149
1900	103	154	3,025	376,195	1,585	138,663	3,531	66,403	23,891	59,725

Year.	Boracite.		Cadmium. Kg.		Coal.		Coal. (Lignite.)		Cobalt Ore.		Cobalt Products.	
1896	171	$9,896	10,667	$20,435	78,993,655	$132,782,104	21,981,901	$12,195,391	181	$9,868	69	$220,624
1897	185	9,663	15,531	44,157	84,253,393	145,665,149	24,222,911	13,324,245	121	6,256	51	166,015
1898	216	10,162	14,943	31,162	89,593,528	160,465,335	26,035,814	14,781,896	84	1,700	44	141,952
1899	171	8,837	13,608	21,336	94,740,829	179,284,452	28,418,598	15,876,512	17	850	46	149,725
1900	217	10,261	13,583	20,511	101,966,158	219,562,750	34,007,542	20,064,519	4	160	52	156,890

Year.	Copper.		Copper and Iron Sulphate		Copper Ore.		Copper Matte		Copper Sulphate.		Epsom Salt.	
1896	25,683	$6,398,780	126	$4,266	707,395	$4,186,321	369	$27,098	2,568	$196,592	1,793	$3,971
1897	25,997	6,696,664	225	8,548	690,338	4,095,679	274	13,157	2,689	225,877	2,248	4,882
1898	27,216	7,277,385	120	4,126	691,866	4,867,052	62	2,170	1,701	139,109	2,061	4,468
1899	20,902	11,336,549	154	6,019	722,884	5,137,918	95	4,045	1,586	142,124	1,793	3,676
1900	27,156	10,348,578	162	6,845	747,601	5,950,743	81	3,510	1,660	151,741	1,511	3,115

Year.	Gold—Kg.		Iron.		Iron Ore.		Iron Sulphate.		Lead.	
1896	755·2	$524,958	4,470,551	$55,144,390	4,053,109	$7,101,832	8,618	$29,383	102,413	$5,621,335
1897	1,067·1	756,184	4,892,059	64,780,081	4,183,596	8,432,766	9,064	33,037	108,880	6,556,528
1898	1,036·3	719,787	5,176,943	69,822,640	4,020,809	8,135,065	9,144	31,007	119,346	7,692,050
1899	1,016·4	708,524	5,644,614	83,302,190	4,295,575	8,780,892	10,186	31,732	116,995	8,433,998
1900	1,076·6	751,253	5,781,892	95,567,025	4,268,069	9,421,592	10,225	35,784	109,803	9,194,077

Year.	Lead Ore.		Litharge.		Manganese and Alloys.		Manganese Ore		Nickel.		Nickel Ore.		Nickel Sulphate.	
1896	138,898	$2,998,433	2,544	$153,432	86	$42,225	43,614	$102,384	822	$713,455	738	$4,540	128	$31,360
1897	133,158	3,122,880	1,999	127,737	113	58,000	45,254	103,137	898	760,562	204	1,580	167	42,327
1898	133,637	3,218,107	2,260	166,554	99	51,250	42,232	96,691	1,106	706,198	79	693	127	21,690
1899	128,942	3,476,974	2,482	191,601	143	81,250	60,379	158,946	1,115	705,125	91	1,067	123	21,246
1900	147,042	4,450,780	2,366	207,531	151	90,710	58,016	165,263	1,980	1,231,801	3,896	19,488	142	31,500

Year.	Ocher and other Mineral Paints.		Petroleum.		Potassium Salts. Kainite.		Potassium Salts. Other Potash Salts.		Pyrites.		Quicksilver. Kg.	
1896.....	2,110	$43,750	1,512	$46,867	616,462	$2,424,132	587,306	$1,786,786	117,545	$303,745	(b)	.....
1897.....	2,400	48,750	2,600	73,088	716,348	2,529,349	640,226	1,898,647	121,766	209,201	4,867	$4,664
1898.....	2,376	51,600	2,545	70,513	744,240	2,560,761	718,957	2,161,101	128,077	220,411	4,717	4,292
1899.....	2,770	57,682	3,405	91,714	744,657	2,559,169	941,055	2,922,148	134,564	234,596	2,611	3,264
1900.....	3,024	65,551	27,731	608,982	857,271	3,036,771	1,264,993	3,596,825	159,792	282,483	1,577	1,640

Year.	Salt. Common.		Salt. Rock.		Selenium.		Silver—Kg.		Silver and Gold Ore.		Sulphur.	
1896.....	288,300	$1,848,166	305,227	$346,952	(b)	.....	288,467	$6,534,058	15	$18,748	2,011	$41,041
1897.....	274,888	1,643,473	310,755	358,697	23	$402	289,960	5,907,572	6	4,901	2,091	42,960
1898.....	286,051	1,640,214	329,959	377,162	65	1,015	291,969	5,776,802	43	2,866	1,757	38,396
1899.....	288,588	1,645,182	331,943	391,408	46	723	293,858	5,983,217	7	30,547	1,419	30,008
1900.....	287,005	1,764,750	354,603	417,750	40	610	260,611	5,421,778	1	7,661	1,179	24,803

Year.	Sulphuric Acid.		Tin.		Zinc.		Zinc Ore.		Zinc Sulphate.	
1896.....	456,781	$2,934,098	804	$231,111	153,082	$11,775,566	729,725	$4,254,351	3,102	$46,723
1897.....	484,289	2,890,702	912	282,384	150,739	12,608,525	663,739	4,219,761	3,583	54,601
1898.....	531,838	3,223,613	979	367,155	154,643	14,686,429	641,671	5,511,655	4,158	65,987
1899.....	573,733	3,617,024	1,461	858,581	152,987	18,215,992	663,763	8 847,039	4,864	77,585
1900.....	566,368	3,636,776	2,001	1,286,810	155,760	15,513,053	636,068	6,397,939	6,026	80,250

(a) From *Zeitschrift für das Berg-, Hütten-, und Salinenwesen.* (b) Not reported.

MINERAL PRODUCTION OF SAXONY. (a) (METRIC TONS AND DOLLARS; 4 marks = $1.)

Year.	Arsenical, Sulphur, and Copper Pyrites.		Barytes.		Bismuth, and Bismuth, Cobalt and Nickel Ores.		Coal. (Not Including Lignite.)		Coal. (Lignite.)		Fluorspar.	
1896....	8,884·9	$27,080	574·2	$1,554	3,108·7	$141,735	4,536,603	$10,778,005	1,035,825	$663,590	805	$1,509
1897....	9,402·0	29,112	218·4	616	3,030·6	131,952	4,571,685	11,563,214	1,073,230	686,358	592	1,110
1898....	6,410·3	16,269	477·9	1,270	3,043·4	136,167	4,436,455	11,820,001	1,180,928	728,156	775	1,453
1899....	7,442·8	23,189	215·8	587	1,161·8	131,679	4,546,756	12,435,239	1,292,348	793,712	1,355	2,541
1900....	8,591·9	27,026	516·4	1,725	594·7	148,192	4,802,700	15,076,017	1,540,512	1,077,035	1,463	2,741

Year.	Galena.		Iron Ocher, Swabian and Colored Earths		Iron Ore.		Limestone and Various Products. (b)		Manganese Ore.		Quartz, Mica and Uranium Ore.	
1896....	2,844·5	$155,848	333·4	$1,054	3,499·4	$4,314	10·0	$6,967	10	$130	20·1	827
1897....	(j)	.....	92·7	643	13,181·1	12,837	65·1	7,682	260	637	39·7	699
1898....	(j)	.....	440·4	1,317	5,671·2	6,197	(j)	8,110	(j)	.....	116·9	1,698
1899....	(j)	.....	70·7	571	8,038·2	12,880	(j)	9,297	50	125	118·0	1,659
1900....	(j)	.....	275·9	1,121	5,840·0	12,094	(j)	8,538	(j)	.....	52·6	1,163

Year.	Silver Ores. (c)		Tin and Tinstone		Wolfram.		Zinc Blende.		Specimens	Totals.	
1896....	13,315·3	$455,183	88·2	$8,555	40 3	$7,149	72·2	$373	706	5,606,044	$12,257,580
1897....	11,428·5	449,625	54·7	5,981	36·7	7,035	111·6	579	540	5,683,437	12,878,552
1898....	14.658·9	467.77	51·0	5,957	50·6	11.597	28·6	89	921	5,649,107	13,215,913
1899....	13,585·3	449.274	71·8	13,750	50·4	12,943	305·9	1,525	739	5,871,570	13,883,700
1900....	12,591·5	506,997	79·5	17,079	42·3	10,994	59·2	176	343	6,373,319	16,891,244

Year.	Manufactured Products. From a Part of the Coal. Briquettes—M.		Coke.		From a Part of the Lignite. Briquettes—M.		Lignite Bricks—M.	
1896.....	1,981	$7,997	77,086	$299,248	123,571	$81,933	58,374	$104,506
1897.....	(k) 3,547	13,517	77,507	331,863	(k) 53,460	107,451	60,166	105,456
1898.....	(k) 5,321	18,363	72,245	340,085	(k) 71,576	143,438	62,244	112,804
1899.....	(k) 8,457	29,659	74,284	362,065	(k) 91,518	181,411	60,954	107,347
1900.....	(k) 11,582	46,160	73,508	423,464	(k) 97,150	220,872	71,767	144,870

METALLIC CONTENTS OF THE MIXED ORES INCLUDED IN THE PRECEDING TABLE WHICH WERE DELIVERED TO THE FISCAL SMELTING WORKS AT FREIBERG. (*a*)

(IN METRIC TONS; 4 marks = $1.)

Year.	Total Mixed Ores.		Arsenic. Tons.	Copper. Tons.	Gold. Kg.	Lead. Tons.	Nickel and Cobalt. Kg.	Silver. Kg.	Sulphur. Tons.	Zinc. Tons.
1896..... ...	24,923	$638,237	303·2	20·0	0·1736	3,887·5	180·1	26,268·0	3,784·9	122·6
1897.....	20,772	477,664	353·1	9·6	0·1396	5,016·2	(*f*)	21,974·5	7,398·3	124·6
1898.....	31,724	658,756	85·4	3·5	(*f*)	5,769·7	(*f*)	21,404·9	5,445·9	305·3
1899.....	20,956	472,089	242·3	2·1	(*f*)	2,717·4	(*f*)	18,306·1	4,070·5	118·2
1900.....	20,794	530,079	171·0	1·4	(*f*)	2,492·6	(*f*)	19,915·6	4,216·2	34·9

PRODUCTS SOLD BY THE FISCAL SMELTING WORKS AT FREIBERG AND THE COBALT WORKS AT SCHNEEBERG, GERMANY. (*a*) (IN METRIC TONS AND DOLLARS; 4 marks = $1.)

Year.	Arsenical Products. (*d*)		Bismuth. Kg.		Cobalt Products.		Copper Sulphate.		Fine Gold. Kg.		Lead.			
											Products. (*e*)		Sheet.	
1896....	882	$90,626	1,112	$1,765	599	$431,318	2,547	$197,421	847	$590,227	5,810	$333,744	830	$50,953
1897....	1,063	127,122	1,624	3,801	628	581,559	1,878	162,881	889	619,881	5,421	382,652	634	41,626
1898....	1,053	131,710	1,375	3,774	631	620,217	1,777	146,164	851	579,519	7,456	496,095	647	45,710
1899....	953	138,572	1,300	3,443	645	705,347	2,550	228,933	832	581,001	6,422	462,557	1,012	77,254
1900....	829	124,587	1,675	4,424	596	768,199	1,545	184,497	899	626,244	4,633	399,906	514	46,813

Year.	Lead.—*Continued.*				Nickel, Speiss.		Fine Silver—Kg.		Sulphuric Acid. (*g*)		Other Chemicals. (*h*)	
	Shot.		Other Manufactures of. (*f*)									
1896....	149	$10,001	213	$14,874	83	$7,195	46,577	$1,063,337	9,238	$97,812	499	$5,788
1897....	142	9,850	224	15,771	75	4,166	72,862	1,465,076	10,788	78,450	472	5,672
1898....	127	9,515	218	16,746	56	3,409	79,555	1,583,071	11,574	102,699	545	5,690
1899....	203	16,851	301	26,759	54	3,469	85,741	1,743,021	11,844	113,776	565	5,485
1900....	153	15,202	152	15,419	30	1,795	83,886	1,751,600	11,265	119,565	519	5,418

Year.	Zinc and Zinc Dust.		Clay and Chamotte Manufactures. (*i*)	Total Value.
1896....	16	$1,347	$13,598	$2,909,008
1897....	120	10,483	16,855	2,907,602
1898....	227	21,978	18,478	3,774,873
1899....	169	21,729	16,402	4,145,102
1900....	29	3,521	14,375	4,088,565

(*a*) From *Jahrbücher für das Berg- und Hüttenwesen im Königreiche Sachsen.* (*b*) Including arsenic powder, slags, washing-sand, granular ore, refuse stones and chippings. (*c*) Including silver-bearing lead, copper, arsenic, zinc and sulphur ores. (*d*) Including arsenious acid, red, yellow and white glass, and metallic arsenic. (*e*) Including assay lead, soft lead, antimonial lead, litharge, lead fume and tin-lead. (*f*) Including lead pipes, lead wire and various lead apparatus. (*g*) Including sulphuric acid of all kinds. (*h*) Including copperas and glauber salt. (*i*) Including tiles, plates, figured stone, muffles, clay and graphite crucibles, and assaying utensils. (*j*) Not reported. (*k*) Quantity stated in tons.

GREECE.

THE statistics of mineral production in Greece are summarized in the following tables:

MINERAL PRODUCTION OF GREECE. (*a*) (*c*) (METRIC TONS AND DOLLARS; 1 drachma—20 cents.)

Year.	Blende.		Calamine, Calcined.		Chrome Ore.		Emery.		Gypsum.		Iron Ore.		Iron Ore, Manganiferous.	
1896..	1,750	$31,520	20,950	$301,680	1,600	$22,400	3,650	$77,745	120	$2,150	225,600	$314,700	166,850	$417,120
1897..	3,118	58,826	22,817	499,357	563	8,087	3,024	64,411	51	918	260,828	375,592	182,850	499,180
1898..	1,189	22,320	30,906	562,490	1,367	18,000	3,932	83,754	83	1,500	287,100	413,230	218,938	641,840
1899..	1,187	30,936	21,770	539,890	4,386	55,310	4,360	92,868	81	1,465	331,030	499,490	294,820	896,500
1900..	(*b*)	.....	18,751	395,270	5,600	70,200	6,328	134,786	129	2,281	279,880	481,394	243,930	782,940
1901..	454	6,400	17,764	274,070	4,580	47,770	5,091	115,446	671	7,190	278,640	414,000	196,152	579,110

Year.	Lead, Soft.		Lead Ore, Argentiferous.		Lead, Argentiferous.		Lead Fume.		Lignite.		Magnesite, Crude.	
1896..	480	$28,900	3,200	$137,600	14,700	$1,325,095	1,550	$10,510	14,000	$28,000	11,600	$34,800
1897 .	520	33,904	2,815	125,174	15,946	1,524,977	2,785	26,333	20,018	40,000	11,311	39,500
1898..	305	21,655	(*b*)	.....	18,888	1,832,136	2,655	27,248	17,310	34,620	14,829	54,100
1899..	291	23,862	(*b*)	.....	18,768	2,156,443	2,584	28,424	12,150	24,300	17,184	63,580
1900..	245	19,650	978	64,974	16,150	1,676,510	2,045	23,720	12,940	25,200	17,277	62,197
1901..	(*b*)	.....	(*b*)	.....	17,644	1,550,520	5,292	37,910	9,726	18,580	13,410	44,680

Year.	Magnesite, Bricks.		Magnesite, Calcined.		Manganese Ore.		Millstones. *Number.*		Puzzolan.		Sea Salt.		Sulphur.	
1896..	(*b*)	.....	(*b*)	.....	15,500	$93,600	(*b*)	$8,200	31,800	$30,100	22,800	$344,280	1,540	$35,500
1897..	826	$18,172	686	$7,550	11,868	73,580	6,975	3,785	42,600	38,340	20,421	308,357	358	7,518
1898..	516	11,352	129	1,160	14,097	90,220	18,500	9,500	70,700	72,114	25,250	363,600	135	2,880
1899..	542	19,512	3,087	71,100	17,600	98,560	12,563	6,307	46,375	39,882	37,125	579,150	1,150	24,150
1900..	534	19,225	807	17,754	8,050	45,170	13,366	8,305	49,426	42,506	22,411	336,165	891	19,424
1901..	500	17,140	2,009	31,090	14,166	52,610	16,400	9,371	80,223	68,190	23,079	351,700	3,212	67,290

(*a*) Statistics communicated by E. Grohmann, Seriphos. (*b*) Not stated. (*c*) There was produced also in 1896 ocher, 40 metric tons, value, $104; in 1899 speiss from lead smelting, 1,100 metric tons ($12,760); in 1900, asbestos, 9 tons ($72); soapstone, 97 tons ($585); speiss from lead smelting, 3,767 tons ($41,566); in 1901, asbestos, 43 tons ($345); soapstone, 150 tons ($1,100).

INDIA.

THE official statistics of mineral production in British India, and the imports and exports, are summarized in the subjoined tables:

MINERAL PRODUCTION OF INDIA. (*a*) (IN METRIC TONS AND DOLLARS; 4 rupees = $1.)

Year.	Alum.		Asbestos. Kg.		Borax.		Clay.	Coal.		Copper Ore.		Fullers Earth.	
1896.....	418	(*b*)	304	$12	340	$30,034	$830,922	3,909,764	$3,065,067	22	$210	(*b*)	.....
1897.....	509	(*b*)	254	10	280	23,022	(*c*)	4,128,330	3.116,647	33	69	318	$125
1898.....	762	$15,750	254	10	184	15,456	(*c*)	4,678,640	3,576,167	(*b*)	.....	(*b*)	.....
1899.....	4	117	51	2	(*b*)	.....	508,862	5,016,055	3,884,968	52	256	(*b*)	.....
1900.....	...	.....	51	2	(*b*)	.....	1,031,665	6,216,882	5,036,555	77	61	(*b*)	.....

Year.	Gold—Kg.		Granite. (*c*)		Graphite.		Gypsum.		Iron Ore.		Laterite.	
1896.....	10.662	$5,314,617	835,697	*d*$124,777	(*b*)	.....	7,605	$1,017	13,996	$22,225	5,867,878	*c*$70,235
1897.....	12.100	5,581,439	633,302	*d*129,381	61	.....	8,187	1,082	44.009	38,075	5,399,794	*c*94,074
1898.....	12,773	6,031,890	866,131	*d*123,815	22	.....	8,390	1,160	50,559	46,902	6,173,887	(*c*)
1899.....	14,214	6,461,560	811.019	*d*136,444	1,548	*c*$5,925	6,546	592	61,697	46,343	6.010,582	*c*493,826
1900.....	15,946	7,094,266	868,759	*d* 72,020	(*b*)	.....	4,415	424	64,095	41,481	565,251	147,259

Year.	Limestone.		Manganese Ore		Mica.		Petroleum—*Gallons.*		Rubies.
1896.....	1,135,730	$128,291	57,782	$113,738	538	$85,617	15,057,094	$448,339	$171,894
1897.....	1,861,309	195,673	74,862	147,500	703	49,751	19,128,828	565,943	200,613
1898.....	1,924,577	(*c*)	61,469	120,900	271	56,265	18,972,388	254,580	217,313
1899.....	2,188,985	371,791	88,520	65,344	630	227,378	32,934,007	471,315	340,998
1900.....	1,201,875	190,102	132,767	425,095	931	221,417	37,729,211	557,831	364,974

Year.	Salt.		Saltpeter.		Sandstone.		Slate. (*c*)	Soapstone. (*c*)		Tin Ore. (*c*)		Trap Rock. (*c*)	
1896....	1,043,171	$1,369,821	16,140	$567,200	1,001,245	*c*$80,521	22,840	$9,708	780	$2,719	82	$20,361	107,956	$5,447
1897....	937,932	1,219,074	12,819	440,630	956,532	*c* 48,328	26,589	10,102	1,008	3,915	62	9,888	140,764	19,629
1898....	1,043,824	1,485,702	11,702	402,560	*c*1,174,454	(*c*)	26,954	10,755	1,839	(*b*)	40	9,572	128,772	(*c*)
1899....	977,240	1,324,548	11,397	408,660	1,070,799	131,369	26,372	13,359	735	5,111	50	17,987	358,871	53,015
1900....	1,021,426	1,146,363	11,709	407,414	400,543	107,662	7,341	6,919	2,339	7,507	106	32,002	756,291	33,188

(*a*) From the *Review of the Mineral Production in India*; and the *Annual General Report upon the Mineral Industry of the United Kingdom of Great Britain.* (*b*) Not stated in the reports. (*c*) Incomplete. (*d*) Represents only a part of the product, about one-half in 1896, 1897, 1898, 1899 and 1900.

MINERAL IMPORTS OF BRITISH INDIA. (a) (IN METRIC TONS AND DOLLARS; 4 rupees = $1.)

Year. (b)	Alum.		Arsenic.		Asphalt.		Brass.		Cement.		Chalk and Lime.		Clay Products. Clays.	
1895–96...	4,050	$99,550	122	$12,705	1,387	$19,502	543	$150,182	36,408	$356,302	1,607	$6,055	2,910	$30,670
1896–97...	2,726	62,372	88	7,870	883	12,002	499	144,675	29,196	278,617	1,745	4,875	2,336	22,720
1897–98...	5,248	115,990	98	9,520	1,082	13,307	670	187,542	37,354	371,690	1,040	5,177	2,788	26,950
1898–99...	3,607	70,637	119	11,490	1,090	12,725	443	136,800	36,170	369,797	1,735	7,757	2,914	24,332
1899–1900.	3,331	87,020	103	13,660	715	11,745	518	205,780	37,058	500,330	2,040	11,250	2,235	25,950
1900–01...	3,278	91,990	140	18,795	1,616	27,265	595	271,810	40,537	541,575	969	5,880	1,858	20,045

Year. (b)	Clay Products.—*Continued.* Brick and Tile. *Number.*		Earthenware and Porcelain.	Earthenware (Piping).	Coal.		Coke.		Copper and Copper Manufactures.		Glassware.
1895–96...	2,328,741	$45,270	$578,555	1,011	21,163	758,799	$3,390,590	14,626	$112,635	c23,968	$5,294,837	$1,852,695
1896–97...	3,915,291	72,475	537,752	1,391	26,400	488,732	2,326,890	13,588	117,352	12,237	2,688,535	1,760,460
1897–98...	4,507,161	69,637	512,605	785	15,370	251,574	1,213,220	15,027	130,160	16,383	3,554,325	1,441,680
1898–99...	3,544,390	69,032	468,372	829	14,162	352,540	1,651,390	11,573	86,567	12,766	2,803,190	1,655,732
1899–1900.	3,641,594	71,420	663,455	663	13,655	404,382	2,451,040	13,899	162,885	4,615	1,763,790	2,555,505
1900–01...	4,008,397	74,925	671,585	780	31,220	110,312	749,665	13,434	209,770	7,998	3,057,110	2,517,255

Year. (b)	Iron, Pig. (d)		Iron and Steel, Manufactures of.		Lead. Ore.		Pig.		Manufactures		Mineral Oils. *Gallons.*	
1895–96...	10,218	$142,490	279,472	$9,599,703	137	$8,712	1,050	$54,400	4,993	$372,178	66,647,921	$6,949,358
1896–97...	13,278	190,152	262,502	9,131,382	309	17,810	709	36,865	5,252	368,720	68,421,148	7,720,697
1897–98...	11,045	155,355	281,253	9,847,455	160	9,855	547	28,302	5,098	351,545	87,325,026	8,494,467
1898–99...	12,407	158,290	239,637	8,169,988	211	13,140	706	38,242	4,204	291,610	76,625,406	7,464,680
1899–1900.	13,389	265,015	211,892	11,135,815	283	24,050	613	55,115	4,318	443,265	70,440,116	9,799,940
1900–01...	9,678	226,710	256,921	15,015,895	186	16,675	732	65,815	5,197	621,215	72,601,898	10,344,790

Year. (b)	Paints and Colors.		Precious Stones.	Quicksilver		Salt.		Stone and Marble.		Tin and Tin Manufactures.		Zinc and Zinc Manufactures.	
1895–96...	9,685	$704,942	1,630,878	160	$152,038	413,787	$1,633,065	43,094	$72,250	2,556	$823,527	4,564	$312,750
1896–97...	9,696	674,395	1,321,700	118	102,992	333,557	1,571,360	24,880	62,930	1,849	551,342	2,277	175,580
1897–98...	9,238	670,680	1,126,225	143	119,050	494,503	2,171,705	36,745	96,485	1,962	554,078	3,185	244,312
1898–99...	10,159	643,257	974,882	115	99,895	418,455	1,653,067	31,200	78,552	1,483	416,930	3,795	291,012
1899–1900.	9,263	884,743	3,091,155	87	113,455	423,302	2,039,985	29,405	98,790	894	461,375	3,916	464,715
1900–01...	11,009	1,033,070	1,924,750	121	170,435	353,465	1,886,690	10,961	70,565	2,179	736,190	3,636	401,690

(a) From the *Tables Relating to the Trade of British India.* (b) Fiscal years ending March 31. (c) Also imported 2 tons copper ore, value $287. (d) Also imported, 1896–97, 2 metric tons iron ore, $82; in 1897–98, 52 metric tons; $735, in 1898–99, 597 metric tons of ore and old iron, $6,932; in 1899–1900, 1,879 metric tons, $39,670; and in 1900–1901, 711 metric tons, $12,220.

MINERAL EXPORTS OF BRITISH INDIA. (a) (IN METRIC TONS AND DOLLARS; 4 rupees = $1.)

Year. (b)	Borax.		Brass.		Coal and Coke.		Copper, and Manufactures of.		Earthenware and Porcel'n.	Glassware.	Jadestone.		Lead.	
1895–96...	340	$30,035	204	$127,325	62,217	$216,450	123	$38,817	$12,842	$14,997	215	$136,538	57	$3,115
1896–97...	280	23,622	188	106,012	138,906	352,810	111	35,930	11,432	12,897	219	153,780	210	8,427
1897–98...	184	16,277	162	76,755	216,261	535,340	84	26,325	10,157	11,717	196	150,025	117	5,127
1898–99...	250	24,107	156	70,937	332,807	838,257	130	40,062	8,802	12,742	228	156,075	193	7,215
1899–1900.	224	31,520	270	138,635	309,459	1,093,370	494	164,975	13,200	21,430	142	284,785	237	12,595
1900–01...	162	25,100	581	196,940	550,290	1,979,560	1,860	574,180	17,735	25,340	218	221,015	35	2,385

Year. (b)	Manganese Ore.		Mica.		Mineral Oils. *Gallons.*		Precious Stones.	Saltpeter.		Stone and Marble.		Tin.	
1895–96.....	23,122	$45,515	452	$268,052	315,118	$38,817	$37,287	21,425	$1,339,865	315	$10,555	13	$3,437
1896–97.....	48,087	94,660	652	288,340	191,424	28,225	34,670	26,845	1,480,410	499	14,072	86	20,362
1897–98.....	80,090	157,507	590	267,142	15,563	2,860	30,970	21,218	996,662	995	16,010	49	10,945
1898–99.....	62,875	125,830	556	202,087	722,686	90,960	29,012	18,363	873,390	688	14,215	43	10,982
1899–1900.....	96,749	254,015	1,148	366,860	1,302,227	218,690	40,995	20,188	1,280,980	1,089	32,605	39	23,120
1900–01.....	132,804	566,715	1,685	507,770	280,507	47,214	30,920	17,600	1,131,775	2,150	31,310	27	15,425

(a) From the *Tables Relating to the Trade of British India.* (b) Fiscal years ending March 31. (c) Not reported.

ITALY.

THE official statistics of mineral and metal production in Italy, together with the imports and exports as reported in the official statistics of the Kingdom, are summarized in the following tables:

MINERAL PRODUCTION AND REFINED PRODUCTS OF ITALY. (*a*) (IN METRIC TONS AND DOLLARS; 5 lire = $1.)

Year.	Alum.		Aluminum. Sulphate.		Alunite.		Antimony.		Antimony Ore.		Asphalt, Mastic and Bitumen.	
1896.....	850	$16,260	2,390	$41,020	6,000	$6,000	588	$72,440	5,086	$60,590	12,490	$75,280
1897.....	1,030	21,180	2,310	40,160	6,500	6,500	404	57,072	2,150	34,864	18,644	89,125
1898.....	1,165	25,060	2,915	54,560	7,000	7,000	380	62,550	1,931	43,822	17,818	111,611
1899.....	945	22,350	2,330	43,287	5,800	5,800	581	87,900	3,791	44,862	41,782	248,034
1900.....	1,097	27,131	2,408	46,467	5,200	7,280	1,174	154,360	7,609	72,468	33,127	201,863

Year.	Asphaltic Rock.		Barytes.		Borax, Refined.		Boric Acid.				Coal. (*b*)	
							Crude.		Refined.			
1896.....	45,456	$177,726	(*c*)	.....	943	$79,279	2,616	$167,424	253	$32,838	276,197	$396,379
1897.....	55,339	189,655	(*c*)	.....	990	83,160	2,704	173,056	260	31,200	314,222	467,111
1898.....	93,750	265,645	12,400	$74,400	702	50,558	2,650	163,600	166	16,590	341,337	495,965
1899.....	81,987	230,589	12,545	87,653	709	51,064	2,674	171,136	129	11,619	388,534	551,844
1900.....	101,738	292,287	14,003	96,010	858	68,656	2,491	169,429	283	28,350	479,896	708,471

Year.	Coal. (Briquettes.)		Coke.		Copper.		Copper Ore.		Gold—Kg.		Gold Ore.	
1896.....	422,409	$2,081,645	426,906	$2,695,109	2,842	$768,160	90,408	$424,719	274·7	$189,024	7,659	$170,609
1897.....	549,050	2,768,350	430,617	2,669,285	2,960	749,954	93,377	431,229	316·0	218,962	10,723	178,010
1898.....	594,500	3,373,900	469,228	2,943,821	3,230	878,509	95,128	426,299	187·9	131,818	9,549	148,826
1899.....	566,000	3,262,000	485,951	3,102,354	3,032	1,164,697	94,764	687,772	113·3	79,095	11,859	91,416
1900.....	703,740	4,750,360	487,831	3,605,303	2,797	1,096,424	95,644	631,808	57·5	39,987	5,840	53,257

Year.	Graphite.		Iron.									
			Ore.		Bar, Sheet, Pipe, Wire, etc.		Pig.		Sheet, Tinned.		Steel.	
1896.....	3,148	$10,193	203,906	$507,973	139,991	$6,606,951	6,967	$192,681	2,918	$256,784	65,955	$4,874,589
1897.....	5,650	11,300	200,709	572,102	149,944	7,176,951	8,393	181,763	6,500	546,000	63,940	4,156,650
1898.....	6,435	17,423	190,110	549,248	167,499	8,173,165	12,387	259,897	7,200	660,000	87,467	5,417,096
1899.....	9,990	55,944	236,549	706,823	197,730	10,961,105	19,218	521,428	8,000	960,000	108,501	6,759,501
1900.....	9,720	55,720	247,278	917,104	190,518	10,312,200	23,990	625,834	10,000	1,200,000	115,887	6,865,153

Year.	Lead.		Lead Ore.		Manganese Ore.		Manganiferous Iron Ore.		Marble.		Petroleum.		Petroleum, Benzine, etc.	
1896..	20,786	$1,162,469	33,545	$892,865	1,890	$20,450	10,000	$20,000	209,428	(*c*)	2,524	$128,894	2,734	$296,147
1897..	22,407	1,462,909	36,200	1,008,525	1,634	15,008	21,262	34,019	236,958	(*c*)	1,932	98,456	3,392	279,533
1898..	24,543	1,646,865	33,930	1,044,248	3,002	18,707	11,150	26,760	271,725	$2,109,440	2,015	117,826	5,040	395,821
1899..	20,543	1,580,423	31,046	1,122,161	4,356	22,432	29,874	77,149	313,744	2,438,624	2,242	118,812	5,384	420,710
1900..	23,763	2,088,469	35,108	1,447,793	6,014	30,995	26,800	67,000	310,336	2,409,410	1,683	98,354	6,077	596,255

Year.	Pumice.		Pyrites. (Cupriferous in part.)		Quicksilv'r.		Quicksilver Ore.		Salt.					
									Brine.		Rock.		Sea.	
1896..	(*c*)	.....	45,728	$108,825	186	$174,840	14,305	$147,570	11,974	$61,298	17,300	$52,024	422,555	$856,072
1897..	(*c*)	.....	58,320	156,028	192	192,000	20,659	157,782	11,725	63,100	19,801	54,404	420,253	885,637
1898..	2,766	$41,678	67,191	165,610	173	173,000	19,201	132,223	11,546	59,568	18,199	61,147	451,426	710,501
1899..	7,300	141,620	76,538	198,859	205	246,000	29,322	191,544	11,021	63,950	17,821	60,468	363,826	514,074
1900..	7,000	154,000	71,616	296,055	260	312,000	33,930	225,476	10,890	73,340	18,331	55,277	338,034	473,823

Year.	Silver—Kg.		Silver Ore.		Sulphur. Crude. (Fused.)		Sulphur. Ground.		Sulphur. Refined.		Talc.	
1896.....	38,075	$382,226	640	$107,251	426,353	$6,134,253	89,292	$1,602,797	71,072	$1,198,447	(c)	.....
1897.....	45,313	917,670	405	85,625	496,658	8,995,647	69,178	1,541,510	85,872	1,874,642	(c)	.....
1898.....	43,437	894,157	435	76,048	502,351	9,708,050	146,001	3,259,999	99,494	2,273,053	12,760	$44,970
1899.....	33,645	720,022	540	116,652	563,697	10,769,342	161,509	3,602,450	110,213	2,481,727	11,000	73,687
1900.....	31,169	672,099	584	79,774	544,119	10,212,903	167,466	3,636,642	157,957	3,464,406	14,415	68,459

Year.	Zinc.		Zinc Ore.	
1896.....	*Nil.*	.....	118,171	$1,496,129
1897.....	250	$22,500	122,214	1,656,065
1898.....	250	27,000	132,099	2,412,333
1899.....	251	27,662	150,629	4,846,666
1900.....	547	65,759	139,679	3,281,696

(*a*) From *Rivista del Servizio Minerario.* (*b*) Includes anthracite lignite, fossil-wood, and bituminous schist. (*c*) Not reported.

MINERAL IMPORTS OF ITALY. (*a*) (IN METRIC TONS AND DOLLARS; 5 lire = $1.)

Year.	Antimony.		Arsenic—Kg.		Asbestos.		Asphaltic Prod. (Bitumen.)		Barytes.		Borax and Boric Acid.	
1896.....	38	$6,112	(*b*)	.....	851	$76,572	11,892	$190,277	549	$14,284	166	$18,249
1897.....	66	10,512	3,200	$928	619	61,890	1,632	26,120	578	15,025	258	24,221
1898.....	58	11,077	700	203	1,186	118,640	1,150	18,405	860	22,365	147	10,786
1899.....	64	13,335	600	182	1,675	167,500	1,473	23,566	936	24,346	123	10,110
1900.....	37	7,704	900	274	1,645	164,510	1,933	30,923	859	22,584	122	11,634

Year.	Cement and Hydraulic Lime.		Chalk.		Clay Products. Brick, Tile, etc.		Clay Products. Kaolin.		Clay Products. Majolica Wares.		Clay Products. Porcelain.	
1896.....	12,810	$115,290	15,716	$110,012	18,504	$129,528	3,775	$30,200	439	$20,293	441	$123,128
1897.....	16,680	150,120	28,937	202,559	19,086	133,602	5,719	45,752	476	24,637	472	126,548
1898.....	12,029	108,261	18,252	127,764	21,681	151,767	9,079	72,632	101	4,922	588	100,519
1899.....	14,391	125,178	13,738	96,166	22,410	156,870	12,105	96,840	461	6,230	894	248,268
1900.....	15,494	139,060	16,436	92,180	25,702	179,914	9,595	76,720	148	7,918	1,003	280,007

Year.	Clay Products.—*Continued.* Potters' Clay and Manufactures.		Clay Products.—*Continued.* Terra Cotta.		Coal.		Copper Ore.		Copper Cement.	
1896.....	787	$120,820	2,675	$84,622	4,081,218	$17,141,116	484	$67,760	1,150	$184,000
1897.....	743	116,980	2,167	69,021	4,259,643	19,594,358	1,611	225,540	1,049	167,840
1898.....	825	129,330	2,122	67,785	4,431,524	27,475,449	5,471	820,650	2,040	354,960
1899.....	773	123,490	2,200	68,554	4,859,556	30,129,246	2,777	555,400	1,328	239,040
1900.....	875	140,050	2,031	63,031	4,947,180	41,056,312	5,290	302,000	1,298	223,640

Year.	Copper, Brass and Bronze.		Copper and Iron Sulphates.		Glass and Manufactures.		Gold. Coin—Kg.		Gold. Unrefined. Kg.		Gold. Man'fact'res Kg.	
1896.....	6,955	$2,592,932	24,255	$2,037,462	9,322	$813,134	1,004	$622,480	2,517	$1,308,840	1,515	$570,446
1897.....	7,999	2,678,833	28,878	2,656,849	11,182	937,282	444	275,280	807	419,640	1,375	459,240
1898.....	7,433	2,645,153	25,560	2,351,538	10,399	863,916	154	95,480	507	263,640	1,844	641,785
1899.....	7,334	3,802,699	27,408	3,453,383	10,303	939,677	181	112,220	326	169,520	1,390	520,170
1900.....	9,249	4,814,284	32,127	4,176,549	11,356	1,119,293	188	116,560	309	160,680	1,348	526,566

Year.	Graphite.		Iron. Ore.		Iron. Pig.		Iron. Wrought.		Iron and Steel. Plates, Rods and Manufactures.		Iron and Steel. Scrap.	
1896.....	204	$12,264	594	$1,425	119,491	$1,911,854	4,820	$327,413	52,202	$6,919,787	162,035	$2,430,526
1897.....	315	18,882	5,831	15,161	156,019	2,496,310	3,801	269,378	88,895	5,179,932	130,938	1,964,076
1898.....	382	26,726	8,723	23,552	169,059	2,874,010	4,076	307,371	98,564	5,533,233	138,426	2,214,811
1899.....	608	42,581	20,799	58,237	191,613	4,213,495	4,158	387,234	142,645	7,132,446	245,616	4,666,710
1900.....	982	68,740	19,205	69,138	160,686	3,856,478	7,405	716,735	149,263	10,444,818	197,415	4,145,721

Year.	Lead. Ore. (c)		Lead. And Alloys in Pigs.		Lead. Manufactures.		Lead Oxide and Carbonate.		Mineral Paints.		Nickel Alloys and Manufactures.	
1896...	9,730	$408,660	1,166	$69,978	192	$39,524	523	$41,087	852	$20,441	411·3	$473,189
1897...	14,854	653,576	1,178	75,424	247	54,481	580	43,211	868	21,305	432·4	473,386
1898...	10,947	508,562	1,481	100,142	435	75,950	647	54,314	692	16,606	257·7	345,798
1899...	7,476	373,800	3,990	319,232	249	51,304	662	60,859	958	23,004	250·0	295,536
1900...	9,134	456,700	3,257	286,727	192	53,301	557	58,705	958	22,997	231·9	359,758

Year.	Petroleum.		Phosphate Rock.		Potash, Ammonia and Caustic Soda.		Potassium Sulphate.		Precious Stones, Manufactures. Kg.	
1896...	70,217	$2,387,388	(b)	.....	9,841	$458,037	431	$24,142	478·9	$1,506,464
1897...	68,973	2,207,139	(b)	.....	11,012	528,537	562	30,375	490·8	2,033,714
1898...	70,654	2,402,253	65,126	$781,500	11,047	493,303	923	50,101	318·6	1,629,008
1899...	71,391	2,998,409	116,283	1,395,396	12,370	583,413	1,297	75,214	350·1	1,333,317
1900...	73,089	3,215,903	140,281	1,683,372	14,077	684,169	1,670	98,554	423·0	1,801,264

Year.	Salt.		Silver. Coin—Kg.		Silver. Unrefined in Bars—Kg.		Silver. Manufactures. Kg.		Quicksilver.		Slag.	
1896...	(b)	.....	22,751	$910,040	2,291	$48,111	6,533	$125,212	80	$27,180	30,275	$363,294
1897...	(b)	.....	26,008	1,040,320	2,434	43,812	5,286	91,453	80	27,270	37,201	409,208
1898...	26,686	$96,070	8,241	329,640	901	17,838	5,673	86,594	39	37,440	51,139	563,197
1899...	(b)	.....	20,605	824,200	1,782	32,789	4,881	80,005	62	68,420	56,549	678,592
1900...	3,367	12,121	29,291	1,171,640	2,678	50,346	4,358	66,901	49	58,800	32,254	387,050

Year.	Sodium Salts. Carbonate.		Sodium Salts. Nitrate. (Crude.)		Sodium Salts. Refined, and Potassium Nitrate.		Tin. Bars.		Tin. Manufactures.	
1896...	18,927	$329,335	11,685	$537,501	541	$40,320	1,763	$581,955	91	$35,156
1897...	20,721	393,699	16,400	705,204	917	69,946	1,520	501,732	81	31,560
1898...	20,845	458,588	19,961	818,409	702	48,478	1,722	688,680	109	50,341
1899...	22,654	498,386	22,385	940,170	671	56,659	1,240	842,992	96	63,380
1900...	23,215	510,734	27,706	1,191,345	511	30,812	1,643	1,183,740	56	39,104

Year.	Zinc. Ore.		Zinc. Oxide.		Zinc. Pigs and Old.		Zinc. Manufactures.		Metals Not Specified. Crude.		Metals Not Specified. Manufactures.	
1896...	(b)	.....	540	$54,020	2,596	$233,640	3,482	$421,918	1,135	$90,768	21	$10,979
1897...	(b)	.....	570	57,000	3,278	295,038	3,556	421,153	1,509	114,661	30	15,756
1898...	216	$4,320	573	63,008	2,813	303,793	3,200	441,066	1,612	128,944	27	14,416
1899...	(b)	.....	804	96,468	3,498	461,776	3,221	523,130	2,726	245,331	15	7,897
1900...	85	1,870	1,054	139,141	3,627	391,738	3,543	491,104	2,737	266,582	43	23,166

(a) From the *Movimento Commerciale del Regno d'Italia*. (b) Not reported. (c) Includes argentiferous lead ore.

MINERAL EXPORTS OF ITALY. (a) (IN METRIC TONS AND DOLLARS; 5 lire = $1.)

Year.	Antimony.		Asbestos.		Asphaltic Product. (Bitumen.)		Barytes.		Borax and Boric Acid.		Cement and Hydraulic Lime.	
1896...	361	$57,760	130	$11,673	13,739	$92,375	66	$1,705	2,719	$352,785	3,871	$30,968
1897...	271	43,344	170	11,893	15,310	244,960	143	3,723	1,618	145,676	5,330	42,640
1898...	338	64,315	208	16,672	19,465	311,440	70	1,828	2,167	143,925	5,192	41,536
1899...	240	50,402	245	19,568	26,402	422,432	45	1,165	2,872	209,783	5,462	43,062
1900...	467	96,140	261	20,864	24,287	388,586	40	1,105	2,114	167,909	6,860	58,510

Year.	Chalk.		Clay Products. Brick, Tile, etc.		Clay Products. Kaolin.		Clay Products. Porcelain.		Clay Products. Potters' Clay and Manufactures.		Clay Products. Terra Cotta.	
1896...	5,593	$27,965	143,648	$809,823	49	$392	99	$24,912	1,143	$157,100	2,852	$97,548
1897...	7,556	37,780	125,925	710,155	93	744	138	38,164	1,292	174,910	2,472	85,653
1898...	6,744	40,504	125,614	711,039	94	752	86	28,476	1,347	196,600	2,751	96,254
1899...	5,386	32,316	136,402	769,182	94	658	124	39,253	1,579	238,040	2,796	102,292
1900...	2,980	14,900	122,388	689,534	179	1,432	96	29,922	1,753	298,940	3,051	106,705

Year.	Coal.		Copper Ore.		Copper, Brass and Bronze.		Copper & Iron Sulphates.		Glass and Manufactures of.		Gold. Coin—Kg.	
1896.....	18,924	$71,481	3,603	$61,251	643	$225,211	71	$5,998	5,867	$1,066,612	2,483	$1,539,460
1897.....	23,191	106,679	2,408	40,936	641	261,764	18	1,638	6,022	1,015,225	1,608	996,960
1898.....	17,749	110,044	2,356	42,408	857	169,986	25	2,300	5,209	849,398	2,566	1,590,920
1899.....	20,803	123,979	1,148	23,900	1,734	808,314	20	2,507	5,930	1,021,111	2,067	1,281,540
1900.....	23,936	200,978	1,179	29,475	1,209	590,658	60	7,839	6,158	1,222,624	2,345	1,453,900

Year.	Gold.—*Con.* Unrefined. Kg.		Graphite.		Iron. Ore.		Iron. Pig.		Iron. Wrought.		Iron and Steel. Plates, Rods and Manufactures.	
1896.....	2,517	$1,308,840	3,727	$29,817	187,059	$448,941	1,378	$22,056	427	$26,006	1,819	$227,305
1897.....	1,351	718,120	4,164	45,806	207,619	539,809	498	7,973	1,434	67,10(	7,148	662,990
1898.....	1,739	904,280	5,145	56,599	217,556	587,401	840	14,280	699	38,870	4,606	533,233
1899.....	1,162	604,240	8,114	89,257	234,515	656,642	378	8,316	611	46,06(	4,817	317,166
1900.....	2,763	1,436,760	7,820	86,020	170,266	613,030	329	7,894	440	32,798	5,610	375,708

Year.	Lead. Ore. (*b*)		Lead. And Lead Alloys in Pigs.		Lead. Manufactures.		Lead. Oxide and Carbonate.		Mineral Paints.		Nickel, Alloys, and Manufactures of.	
1896.....	4,731	$151,392	1,419	$85,140	1,441	$141,019	489	$47,823	2,412	$53,055	35	$34,230
1897.....	4,747	161,398	2,790	178,586	1,410	141,672	461	45,829	2,318	46,364	27	25,270
1898.....	4,492	157,220	5,870	410,896	1,764	189,362	414	41,418	2,884	57,684	29	28,536
1899.....	3,129	118,902	2,497	199,736	910	133,925	389	42,004	2,784	55,678	33	96,856
1900.....	3,741	142,158	5,018	442,823	983	176,146	367	39,640	2,977	59,534	3	4,080

Year.	Potash, Ammonia, and Caustic Soda.		Quicksilver.		Salt, Sea and Rock.		Silver. Coin—Kg.		Silver. Unref'd in Bars, etc.—Kg.		Slag.	
1896.....	88	$7,453	155	$189,590	171,741	$360,656	28,377	$1,135,080	26,854	$644,496	4,753	$4,753
1897.....	66	5,492	236	212,670	176,522	247,131	72,605	2,904,200	50,508	1,050,462	8,847	8,847
1898.....	85	11,718	244	234,432	126,867	197,913	8,241	329,640	68,607	1,427,026	6,861	6,861
1899.....	120	10,422	223	243,850	114,056	136,867	32,085	1,283,400	33,432	687,558	4,898	5,878
1900.....	142	8,616	259	310,320	112,902	126,450	10,501	420,040	25,310	546,696	4,222	5,067

Year.	Sodium Salts. Carbonate.		Sodium Salts. Nitrate. (Crude.)		Sodium Salts. Refined, and Potassium Nitrate.		Stone. Alabaster, Crude.		Stone. Building Stone.	
1896.....	279	$4,855	51	$2,351	306	$23,751	289	$7,514	23,580	$93,699
1897.....	275	5,225	151	6,506	344	26,482	269	6,989	36,229	117,705
1898.....	391	8,599	79	3,255	256	17,323	457	11,882	35,945	178,024
1899.....	438	9,638	136	5,725	124	8,823	714	18,577	58,904	259,519
1900.....	486	10,690	58	2,494	129	10,808	489	12,724	54,051	266,496

Year.	Stone.—*Continued.* Marble, Crude.		Stone.—*Continued.* Marble and Alabaster.		Sulphur, Crude and Refined.		Tin. Pigs, Bars, etc.		Tin. Manufactures.	
1896.....	80,750	$969,000	68,639	$1,987,828	356,370	$5,452,461	10	$3,267	89	$33,994
1897.....	83,081	996,978	62,750	1,864,862	358,932	6,819,713	29	9,699	109	41,452
1898.....	83,404	1,060,848	68,150	2,154,092	405,823	8,359,962	34	13,760	177	80,169
1899.....	96,485	1,181,820	84,104	1,768,193	424,018	8,692,375	69	47,124	176	114,864
1900.....	61,650	1,099,800	72,619	2,378,338	479,139	9,496,942	147	108,426	153	104,288

Year.	Zinc. Ore.		Zinc. Oxide.		Zinc. Pigs and Scrap.		Zinc. Manufactures.	
1896.....	115,454	$1,847,264	48	$4,840	33	$2,979	8	$2,644
1897.....	133,125	2,130,000	189	18,910	309	27,783	63	13,142
1898.....	130,064	2,601,280	110	12,122	156	16,637	14	3,021
1899.....	140 107	3,362,568	123	14,820	227	29,977	21	4,249
1900.....	111,870	2,461,140	102	13,517	359	38,781	24	5,558

(*a*) From the *Movimento Commerciale del Regno d'Italia.* (*b*) Includes argentiferous ore.

JAPAN.

THE mineral production of Japan is reported in the subjoined tables.

MINERAL PRODUCTION OF MINES IN JAPAN WORKED BY THE GOVERNMENT. (*a*)
(In metric tons.)

Year	Gold.—Kg.	Silver.—Kg.	Copper.	Iron—Pig.	Lead.	Antimony.		Manganese	Salt. *Hektoliters.*
						Ore.	Metal		
1894.	794·78	72,726·48	19,942·66	18,467·92	1,464·80	1,170·58	408·32	13,257·47	11,411,283·77
1895.	905·14	72,367·89	19,150·96	25,832·11	1,850·32	1,045·69	640·57	17,041·02	10,913,474·30
1896.	963·61	64,644·83	20,113·57	27,420·77	1,857·66	827·58	517·28	17,967·05	9,443,459·79
1897.	1,038·38	54,387·40	20,424·67	28,039·88	773·15	348·22	824·20	15,447·51	11,144,672·77
1898.	1,161·27	60,547·04	21,060·20	23,651·77	1,695·79	1,006·08	233·16	11,517·56	11,481,876·58
1899.	1,678·05	56,264·00	24,317·90	23,076·36	1,891·51	713·33	229·88	11,355·70	10,482,500·78

MINERAL PRODUCTION OF JAPANESE PRIVATE MINES. (*a*) (IN METRIC TONS.) (*b*)

Year.	Antimony.		Arsenic Kg.	Coal.	Copper.	Copperas	Gold. Kg.	Graphite.	Iron.	Lead.	Manganese Ore.
	Ore.	Metal.									
1896 (*g*).	897·6	517·3	6,043·4	5,010,689	20,114	868·6	963·69	215	27,420	1,957·7	17,967
1897 (*g*).	348·2	824·5	13,061·4	5,888,157	20,425	4·2	1,038·38	391	28,040	772·3	15,448
1898 (*g*).	1,006·1	233·2	7,141·0	6,696,033	21,060	20·1	1,161·27	347	23,652	1,705·5	11,517
1899 (*g*).	712·0	229·0	5,000·0	6,721,798	24,318	864·0	1,679·39	55	23,076	1,988·8	11,340
1900 (*g*).	81·0	349·0	5,000·0	7,429,457	25,304	932·0	2,130·00	94	22,712	1,877·0	15,228

Year.	Ocher, Red.	Petroleum, Refined.	Quicksilver. Kg.	Silver. Kg.	Sulphur, Refined	Tin.
1896 (*g*)	9·7	31,314	1,762	64,302·7	12,540	50·0
1897 (*g*)	35·7	34,743	2,683	54,387·4	13,606	47·7
1898 (*g*)	7·9	42,184	1,401	60,547·0	10,339	42·7
1899 (*g*)	28·0	{72,478,737	(*f*)	56,308·5	10,241	18·5
1900 (*g*)	33·0	{121,906,240	2,700	58,953·0	14,435	12·0

(*a*) From *Résumé Statistique de l'Empire du Japon*, Tokio, and special reports from the Japanese Government. The data contained in the table of production of the Government mines are nearly exact, but those contained in the table of private mines, being the figures furnished by the mine owners themselves, are only an approximation and considerably less than the actual figures. (*b*) In making the conversions from the Japanese units to metric tons, hektoliters and dollars, the following relations were employed: 1 kwan = .0037565 metric tons; 1 koku = 1·8039 hektoliters; 1 yen = $1; 1 kg. = 32·151 troy ounces. (*c*) Crude product. (*d*) Number of liters. (*f*) Not reported. (*g*) Includes production of Government mines. (*h*) Number of liters. (*i*) Liters of crude oil.

MINERAL IMPORTS OF JAPAN. (*a*) (IN METRIC TONS AND DOLLARS.)

(1 kin = 0·00060104 metric tons; 1 yen = $1.)

Year.	Brass.				Coal.		Coke.		Copper.				Gold.
	Crude and Old.		Tubing.	Other M'f'res.					Sheet, Rod, and Old.		Tubes, and oth'r M'f'res.		Coin and Bullion.
1896..	47	$20,188	$92,300	$41,243	50,315	$519,380	6,179	$42,537	91	$46,507	$94,306		$10,217,458
1897..	20	10,496	89,170	41,092	70,229	578,570	7,600	56,154	76	43,899	201,833		64,313,493
1898..	37	13,872	167,962	36,250	42,297	399,188	10,099	83,264	101	58,486	170,975		37,027,753
1899..	42	17,848	89,273	15,564	51,154	937,095	6,074	134,588	127	83,763	131,421		20,060,696
1900..	46	23,450	242,172	26,624	98,660	2,100,055	9,933	314,690	122	104,463	243,424		8,967,198

Year.	Iron.									
	Pig.		Bar and Rod.		Plate and Sheet.		Various Manufactures. (*b*)		Railway Materials	Pipe and Tubes, and other M'f'res. (*c*)
1896.....	39,028	$739,556	50,464	$2,359,705	27,642	$1,659,417	36,306	$2,641,885	$1,280,480	$1,534,259
1897.....	43,633	934,010	55,236	3,046,182	23,883	1,724,913	33,944	2,663,807	2,001,119	1,734,987
1898.....	66,702	1,400,755	73,851	4,061,805	23,179	1,405,855	32,973	2,905,246	2,552,823	1,807,977
1899.....	45,978	965,544	49,126	2,603,676	26,401	2,220,414	42,266	4,775,158	260,170	1,389,474
1900.....	22,545	962,910	55,795	5,243,407	41,577	4,080,542	37,815	5,837,494	2,645,141	4,119,887

Year.	Iron and Steel for Rails.		Steel, including Wire and Wire Rope.		Steel Manufact'res	German Silver.		Kerosene. *Hektoliters.*		Lead.	
										Pig.	
1896.....	65,387	$2,595,450	6,810	$1,022,108	$446,275	44·4	$39,830	2,213,073	$6,331,036	2,411	$257,883
1897.....	87,076	3,325,005	4,227	577,260	358,255	44·4	41,790	2,472,669	7,667,350	2,298	257,805
1898.....	69,256	2,631,721	6,823	1,256,150	135,846	18·0	16,450	2,436,413	7,552,880	3,112	365,202
1899.....	11,449	435,054	5,983	1,299,497	197,040	24·8	26,075	2,554,230	7,918,149	3,092	412,155
1900.....	64,415	4,753,371	5,423	1,511,031	638,266	35·4	40,993	3,230,577	14,162,651	6,075	927,152

Year.	Lead—*Continued.*			Nickel.		Plumbago. Kg.		Quicksilver.		Silver.	Tin.	
	Sheet and Tea.		Pipe.							Coin and Bullion.		
1896..	2,147	$259,593	144,504	28	$30,933	36,020	$8,075	78	$130,303	28,924,750	270	$146,413
1897..	1,972	269,638	76,910	44	50,321	155,595	15,413	80	156,527	17,153,220	264	145,174
1898..	1,339	199,402	38,772	127	150,600	31,169	6,520	89	176,303	5,536,028	359	227,257
1899..	1,492	256,011	154,320	42	50,991	14,547	4,058	92	219,012	82,905	366	361,286
1900..	1,833	362,302	57,692	86	123,812	18,570	5,545	101	258,698	2,550,637	399	473,103

Year.	Tin—Plate.		Yellow Metal.					Zinc.				All Other Metals and M'f'res.
			Plates.		Rods.		M'nfactures.	Ingot.		Sheet and Old.		
1896.....	2,626	$251,344	172	$74,940	24	$9,403	$375	1,078	$144,240	2,991	$512,241	$1,773,014
1897.....	5,677	559,654	116	51,419	13	6,334	4,703	836	127,708	4,164	799,930	1,053,688
1898.....	4,012	411,421	57	23,696	6	2,710	1,820	532	80,991	3,224	643,824	648,120
1899.....	3,946	569,923	56	31,722	6	3,460	2,310	1,031	259,606	3,947	1,051,538	456,644
1900.....	4,596	832,149	60	36,072	8	4,280	3,560	3,028	686,080	3,768	977,702	917,053

(*a*) From data specially furnished THE MINERAL INDUSTRY by the Japanese Government. (*b*) Includes old iron, hoop and band, roofing or corrugated and galvanized, nails, and galvanized telegraph wire, iron wire and wire nails (old), and other manufactures. (*c*) Includes also anchors and chain cables, screws, bolts, nuts, etc., and other iron ware.

MINERAL EXPORTS OF JAPAN. (*a*) (IN METRIC TONS AND DOLLARS.)

(1 kin = 0·00060104 metric tons; 1 yen = $1.)

Year.	Antimony.			Brass.			Bronze.			Coal.	
	Metal.		M'factures.	Wire.		M'factures.	Ingot.		M'factures.	For Ships' Use.	
1896	624	$83,806	$104,010	223	$108,612	$35,526	54	$14,570	$180,318	588,963	$2,636,324
1897	1,577	267,548	63,331	147	72,414	66,388	27	8,373	183,022	582,031	3,229,024
1898	1,338	216,598	51,130	218	112,052	19,712	*Nil.*	.....	207,345	381,426	2,928,177
1899	1,045	206,515	58,468	148	92,006	17,862	*Nil.*	.....	230,143	473,919	3,380,135
1900	377	107,707	75,777	147	102,759	17,105	*Nil.*	.....	208,173	946,763	6,328,448

Year.	Coal—*Continued.*				Coke.		Copper.			
	Dust.		Other Kinds.				Ingot.		Old.	
1896	299,102	$930,704	1,350,458	$5,312,227	3,399	$29,114	6,756	$2,423,116	0·23	$113
1897	188,132	859,514	1,366,498	7,457,262	2,950	45,384	2,741	1,075,945	6·81	2,077
1898	(*b*)	.....	1,805,364	12,240,621	3,381	56,914	385	160,583	*Nil.*	.....
1899	(*b*)	.....	2,013,695	11,784,730	3,556	57,243	96	51,481	*Nil.*	.....
1900	(*b*)	.....	2,402,785	13,703,654	5,221	86,610	70	45,750	*Nil.*	.....

Year.	Copper—*Continued.*							Gold.	Iron Wares.
	Refined.		Slab.		Wire.		M'factures.	Coin and Bullion.	
1896	6,134	$2,461,039	1,644	$594,448	72	$33,717	$135,079	$1,996,576	$105,481
1897	6,172	2,680,807	5,045	2,017,947	93	46,947	223,234	8,863,798	178,037
1898	16,069	7,106,491	144	75,481	83	46,998	182,040	46,231,343	200,595
1899	21,208	11,331,876	136	99,381	56	40,278	59,136	8,768,365	185,220
1900	20,407	12,680,184	190	137,992	79	58,490	75,829	51,761,620	247,538

Year.	Other Metal Wares.	Manganese Ore.		Silver. Coin and Bullion.	Sulphur.		Other Mineral Products.	Total.
1896	$358,126	20,986	$274,434	$9,602,308	12,325	$308,588	$1,920	$27,759,986
1897	485,862	14,665	205,318	10,355,365	9,209	321,341	1,396	38,710,334
1898	287,556	9,985	156,382	40,706,138	12,627	477,018	(*c*)	111,513,119
1899	346,992	9,395	152,687	2,409,682	16,684	574,867	(*c*)	39,846,779
1900	286,179	12,902	224,396	4,945,443	17,836	698,283	(*c*)	91,791,936

(*a*) From data furnished to THE MINERAL INDUSTRY by the Japanese Government. (*b*) Included in other kinds. (*c*) Not stated.

MEXICO.

THE Mexican Government collects no statistics of production; those compiled by THE MINERAL INDUSTRY, which represent all the important substances, will be found under the respective captions "Lead," "Copper," "Coal," etc.

MINERAL EXPORTS OF MEXICO. (*a*) (IN METRIC TONS AND MEXICAN DOLLARS.) (*c*)

Year.	Antimony Ore.		Asphalt.		Building Material.		Coal.		Copper. Ore.		Copper. Ingot.	
1897	5,873	$71,835	10	$282	1,808	$7,858	105,298	$434,624	1,094	$176,391	16,858	$3,829,331
1898	5,932	98,815	(*b*)	.....	597	3,561	118,553	486,596	13,146	3,738,738	10,303	2,314,790
1899	10,382	115,292	47	1,623	956	5,923	118,192	453,303	223	54,828	25,293	7,915,827
1900	2,313	23,319	627	12,845	2,623	9,804	38,676	157,282	408	49,736	27,970	9,445,498
1901	5,103	51,064	145	5,526	637	3,265	17,281	70,921	6,044	1,573,454	33,021	10,952,472

Year.	Gold. Coin.	Gold. Ore.	Gold. Bullion.	Gold. Cyanide	Gold. Sulphide.	Graphite.		Gypsum.	
1897	$202,223	$365,226	$6,220,765	$226,986	$33,916	759	$6,698	2,095	$7,775
1898	(*b*)	1,037,202	6,493,735	294,730	64,061	(*b*)	.....	1,650	8,250
1899	183,474	335,849	7,017,286	115,961	266,782	2,305	22,847	1,050	5,250
1900	192,456	306,392	7,435,864	128,675	177,193	2,561	25,650	1,600	8,000
1901	210,431	284,917	8,329,084	177,999	82,267	762	7,615	800	3,504

Year.	Iron Ore.		Jewels and Precious Stones. *Grams.*		Lead. Ore.		Lead. Base Bullion.		Marble.		Pearls—*Carats*	
1897	(*b*)	.....	3,880	$5,026	1·9	$87	60,029	$3,006,821	2,176	$185,004	1,420	$6,000
1898	21	$206	11,241	27,867	(*b*)	.....	60,918	3,291,014	469	46,724	*d*327	3,500
1899	(*b*)	.....	2,489	801	1·0	175	67,441	3,885,747	370	33,220	.....	17,000
1900	(*b*)	.....	1,447	875	468·0	11,425	74,944	4,278,008	1,030	108,759	(*b*)	.....
1901	89	3,535	3,182	542	(*b*)	.....	79,497	4,599,073	1,082	104,751	(*b*)	.....

Year.	Quicksilver. Kg.		Silver. Coin.	Silver. Ore.	Silver. Slag.	Silver. Bullion.	Silver. Sulphide.	Silver. Cyanide	Tin.	
1897	1,845	$3,150	$21,925,347	$11,401,176	$39,800	$35,775,125	$1,663,581	$123,246	0·6	$40
1898	(*b*)	.....	(*b*)	11,048,358	46,488	37,137,599	1,663,501	257,342	(*b*)	.....
1899	(*b*)	.....	5,580,834	10,766,099	4,810	37,585,911	1,929,085	76,942	.....	.....
1900	(*b*)	.....	22,679,655	12,495,524	87,888	41,468,745	1,898,646	67,607	·096	43
1901	(*b*)	.....	12,038,158	9,615,939	92,598	36,348,374	2,141,229	259,819	(*b*)	.....

(*a*) From the *Estadistica Fiscal*. The figures for the calendar years were arrived at by combining those of the successive semesters of the different fiscal years. Additional exports 1898: salt, 1,533 metric tons, $13,449; zinc ore, 1,001 metric tons, $10,016. (*b*) Not reported. (*d*) There was also exported pearls, 42 g., $1,000. (*c*) The average value of the Mexican dollar in New York was, in 1897, $0·4671: in 1898, $0·4641; in 1899, $0·473; in 1900, $0·509; in 1901, $0·490.

NOTE.—There was exported of zinc in 1900, 638 metric tons, worth $6,384; of zinc ore, 1,027 tons, worth $9,385; of salt, 1,518 tons, worth $4,151. Of minerals classed in the *Boletin de Estadistica Fiscal* as "other mineral products not specified," there were exported 749 tons, valued at $5,947. Additional exports in 1901: zinc ore, 166 tons, worth $16,639; salt, 426 tons, worth $3,828 and mineral products not specified, 38 tons, worth $6,202.

NORWAY.

THE official statistics of mineral production, imports and exports, are summarized in the following tables:

MINERAL PRODUCTION OF NORWAY. (*a*) (IN METRIC TONS AND DOLLARS; 1 krone—27 cents)

Year.	Apatite. (*b*)		Cobalt Ore.		Copper Ore.		Feldspar. (*b*)		Iron Ore.	
1895.....	1,601	$23,760	45	$4,050	21,869	$318,835	9,780	$44,901	1,250	$2,349
1896.....	1,106	17,280	29	2,700	29,910	306,747	12,222	54,540	2,000	3,780
1897.....	872	12,960	24	2,700	27,606	303,907	17,392	79,650	3,627	5,670
1898.....	3,593	53,352	21	2,160	37,047	425,466	11,355	49,059	4,425	7,992
1899.....	1,500	22,140	*Nil.*	.....	43,358	589,140	19,260	78,080	4,576	8,100

Year.	Nickel Ore.		Pyrites, Iron and Copper.		Rutile. Kg.		Silver Ore and Native Silver.		Zinc and Lead Ore.	
1895.....	494	$1,080	49,005	$194,400	28,000	$8,100	490	$95,850	(*c*)	.....
1896.....	315	.....	60,507	261,900	30,000	9,720	527	108,000	450	$3,645
1897.....	*Nil.*	.....	94,484	390,150	32,000	5,400	642	103,950	908	7,290
1898.....	*Nil.*	.....	89,763	386,596	35,000	5,940	497	89,640	320	2,592
1899.....	*Nil.*	.....	95,636	461,130	30,000	4,590	429	82,870	379	2,970

Metallurgical Production.

Year.	Cobalt—Kg.		Copper and Copper in Mattes.		Gold.	Iron, Pig and Cast.		Iron, Bar and Steel.		Nickel.		Silver—Kg.	
1895.....	2,500	$8,100	958	$184,950	$2,160	348	$3,942	379	$19,440	17	$10,530	5,000	$105,300
1896.....	29	2,700	1,067	227,610	9,450	335	3,780	400	21,060	16	8,100	4,664	129,600
1897.....	24	2,700	1,054	252,450	675	417	4,590	452	23,760	*Nil.*	.....	5,372	101,790
1898.....	21	2,160	941	238,680	1,539	231	2,700	379	20,520	*Nil.*	.....	4,802	95,850
1899.....	*Nil.*	.....	1,209	378,000	2,700	406	4,590	666	33,750	5	2,700	4,600	89,100

(*a*) From *Tabeller vedkommende Norges Bergvaerksdrift*, *Statistisk Aarboy for Kongeriget Norge*, 1896, and from *Meddeleser fra Det Statistiske Centralbureau*, No. 7, 1899, published by Det Statistike Centralbureau, Christiania. There were also produced in 1895, molybdenite 4,000 kg., $2,160, and chrome ore 190 metric tons, $2,295. (*b*) Export returns, which approximately represent the production. (*c*) Not reported.

MINERAL IMPORTS OF NORWAY. (*a*) (IN METRIC TONS AND DOLLARS; 1 krone —27 cents.)

Year.	Borax and Boric Acid. Kg.		Cement and Hydraulic Lime. *Hektoliters.*		Coal, Coke, and Cinders—*Hektoliters.*		Copper and Brass. Plates, Bolts, and Bars.		Copper and Brass. Wares.		Glass and Glassware.	
1896..	38,305	$4,671	16,028	$137,052	14,201,090	$3,642,570	1,074	$290,061	479	$330,696	3,729	$449,577
1897..	44,495	4,941	18,784	174,258	15,374,572	4,234,167	1,140	307,827	591	495,802	4,262	548,802
1898..	71,590	6,804	25,403	239,057	15,409,902	4,659,957	1,064	316,089	807	643,248	3,905	411,615
1899..	62,060	5,940	*d* 38,251	385,857	*d* 1,478,080	6,485,076	1,000	391,473	1,120	928,071	3,229	412,844
1900..	71,124	6,210	24,511	244,890	*d* 1,504,160	9,491,480	696	281,880	1,164	877,020	2,874	373,940

Year.	Iron. Pig and Cast.		Bars, Hoops, Ships' Knees, etc.		Ships' Anchors and Cables.		Rails.		Nails, Spikes, Bolts, Screws, etc.		Other Manufactures of Iron	
1896.....	20,201	$252,801	26,552	$890,433	1,090	$67,689	4,315	$116,505	1,760	$104,544	34,323	$2,762,208
1897.....	21,606	289,791	29,038	1,013,364	1,367	87,237	7,637	247,428	2,097	153,738	47,494	4,590,918
1898.....	23,106	339,579	26,203	951,345	1,485	105,057	10,327	362,475	2,067	159,921	62,197	5,450,868
1899.....	21,445	395,550	25,379	1,099,494	1,394	104,868	8,137	281,205	1,529	130,842	78,827	7,091,946
1900.....	20,844	467,740	23,010	1,198,260	1,203	114,480	11,952	458,190	1,219	103,410	58,040	5,659,200

Year.	Steel.		Locomotives and Machines.	Lead, in Pigs and Sheets.		Lead White and Zinc Oxide.		Paraffin Oil, Petroleum, etc.		Potash.	
1896.....	2,754	$156,141	$1,895,994	653	$40,527	1,192	$99,738	35,823	$1,160,676	945	$79,063
1897.....	4,350	246,645	2,058,885	848	54,972	1,119	93,636	39,810	1,021,118	919	76,928
1898.....	2,428	144,234	2,437,371	732	51,408	1,491	140,866	36,504	867,031	754	63,099
1899.....	2,652	164,673	2,893,509	869	66,744	1,296	139,995	42,182	1,138,914	803	71,496
1900.....	2,085	152,010	2,259,630	670	59,670	1,216	131,490	39,657	1,070,820	633	59,940

Year.	Salt. *Hektoliters.*		Saltpeter.		Soda.		Sulphur. (*b*)		Tin, in Blocks, etc.		Zinc, in Plates, Bars, etc.	
1896.....	1,179,198	$439,813	308	$23,947	5,156	$55,674	2,347	$227,124	142	$49,788	1,101	$107,055
1897.....	1,645,716	630,963	277	15,708	5,492	59,319	10,701	260,087	236	82,917	1,102	107,088
1898.....	1,273,405	488,211	477	34,776	4,823	52,083	9,589	258,908	257	96,307	1,370	162,729
1899.....	*d*134,588	508,734	278	20,250	4,555	61,506	10,734	299,818	546	314,226	1,509	202,905
1900.....	*d*143,412	619,380	356	25,920	4,576	61,880	14,827	400,410	149	100,340	1,254	149,040

MINERAL EXPORTS OF NORWAY. (*a*) (IN METRIC TONS AND DOLLARS; 1 krone = 27 cents.)

Year.	Apatite.		Clay Products.				Cobalt Ore—Kg.		Copper.			
			Bricks. *Thousands.*		Earthenware.				Ore.		Ingot.	
1896.....	1,160	$17,226	10,008	$48,654	365	$39,420	33,800	$8,208	30,367	$409,941	565	$129,573
1897.....	872	12,960	11,711	59,454	260	27,378	45,000	9,720	15,111	204,012	552	131,031
1898.....	3,593	53,352	15,534	69,677	2	243	25,000	5,400	13,587	189,411	444	113,886
1899.....	1,500	22,275	11,949	56,457	2	270	*Nil.*	.....	7,198	116,618	747	242,001
1900.....	300	4,590	5,266	17,010	2	270	*Nil.*	.....	5,756	93,150	723	253,800

Year.	Copper—*Con.*		Feldspar.		Glassware.		Iodine—Kg.		Iron.			
	Old Metal.								Ore.		Pig and Old.	
1896.....	712	$86,454	12,223	$54,459	1,231	$94,581	1,959	$11,097	2,051	$3,888	5,493	$62,289
1897.....	670	81,459	17,392	79,839	1,432	78,894	2,395	11,151	4,242	8,019	4,631	53,136
1898.....	1,206	156,249	11,355	49,059	841	31,212	5,474	29,565	4,601	8,694	3,844	44,118
1899.....	1,688	224,316	19,260	78,008	840	26,838	16,180	87,372	12,517	23,652	6,065	69,822
1900.....	1,168	268,110	17,609	71,280	1,531	40,230	11,210	49,680	27,158	55,080	8,141	98,320

Year.	Iron.—*Continued.*				Steel.		Machinery.		Nickel Ore. Kg.	
	Bars and Hoops.		Nails and Spikes.							
1896.....	12	$459	10,664	$747,819	132	$7,830	714	$192,915	(*c*)	.....
1897.....	56	2,376	9,097	636,552	167	9,936	992	267,840	(*c*)	.....
1898.....	25	1,134	7,270	489,402	158	9,369	507	136,971	30,000	$135
1899.....	337	16,848	6,089	463,833	377	22,410	464	125,928	63,200	351
1900.....	135	8,640	5,643	460,350	220	17,820	811	218,970	272,000	1,630

Year.	Pyrites.		Silver Ore—Kg.		Stone, Ashlar.		Whetstones.	
1896.....	41,062	$140,265	173,500	$7,261	66,233	$312,957	205	$13,851
1897.....	70,552	238,113	118,900	3,861	74,492	367,065	112	7,587
1898.....	67,502	236,925	79,000	2,565	98,692	546,264	137	9,261
1899.....	83,912	294,543	14,160	972	104,933	566,649	170	11,475
1900.....	84,604	456,840	90,210	4,860	100,914	490,320	136	9,180

(*a*) From *Statistisk Aarbog for Kongeriget Norge.* (*b*) Inclusive of flowers of sulphur. (*c*) Not reported. (*d*) Metric tons.

PORTUGAL.

THE mineral statistics of Portugal are summarized in the subjoined table, for which we are indebted to the courtesy of Senhor Severiano Augusto da Fonseca Monteiro, chief of the Reparticao de Minas, Ministerio das Obras Publicas of Portugal.

The statistics of mineral production in Portugal in years prior to 1896 may be found in THE MINERAL INDUSTRY, Vol. II. and Vol. VII. Statistics of the that the mineral industry of Portugal has not yet attained much importance, the output of copper and copper ore forming the chief part of the total. This is principally the production of Mason & Barry Co., Ltd.

MINERAL PRODUCTION OF PORTUGAL. (*a*) (IN METRIC TONS AND DOLLARS; 1 milreis = $1·08.)

Year.	Antimony Ore.		Arsenic.		Coal. (Anthracite.) (*b*)		Coal. (Lignite.) (*b*)		Copper Ore.		Copper. (Cement.)	
1896..	595	$28,917	(*c*)	.....	8,743	$17,944	8,000	$18,306	436	$10,535	3,453	$467,897
1897..	418	28,063	523	$20,369	7,996	32,816	9,342	24,215	241	4,496	3,304	408,262
1898..	245	6,736	751	44,764	10,250	87,032	12,291	52,656	290	12,799	3,149	533,581
1899..	59	2,123	1,083	61,356	11,930	46,398	10,269	41,161	408	29,920	2,521	520,099
1900..	88	554	1,031	62,522	24,066	90,777	(*c*)	.....	(*c*)	.....	2,948	513,226

Year.	Copper Pyrites.		Copper Pyrites. (Dressed.)		Gold Ore.		Iron Ore.		Lead Ore. (Galena.)		Manganese Ore.	
1896.....	43,665	$139,525	163,775	$224,634	(*c*)	.....	(*c*)	.....	1,338	$30,236	1,494	$14,679
1897.....	66,473	178,014	210,265	287,254	17·0	$12,085	(*c*)	.....	2,180	56,300	1,652	11,596
1898.....	54,368	183,899	248,218	366,258	6·8	4,687	2,519	$3,265	3,242	109,480	907	2,595
1899.....	71,576	358,128	275,658	378,018	13·0	78	15,078	25,564	3,468	104,627	3,949	21,484
1900.....	57,540	183,550	345,330	539,044	*e* 2·6	1,728	19,803	46,247	3,620	116,346	1,971	10,437

Year.	Silver—Kg.		Tin Ore.		Tungsten Ore.	
1896	(*c*)	.....	6	$756	14·0	$3,640
1897.....	79	$2,042	*d* 9	2,550	29·4	7,263
1898.....	119	2,362	102	23,278	59·3	16,714
1899.....	(*c*)	.....	30	9,418	55·0	13,513
1900.....	(*c*)	.....	81	26,017	49·0	8,677

(*a*) From a report specially furnished THE MINERAL INDUSTRY by Senhor Severiano Augusto da Fonseca Monteiro, Chief of the Department of Mines of the Ministerio das Obras Publicas. (*b*) Consumed in the country. (*c*) No report. (*d*) Includesmetallic tin and cassiterite. (*e*) Gold metal, kilograms.

RUSSIA.

THE official statistics of mineral production, imports and exports, are given in the subjoined tables. The Russian official statistics of production are somewhat tardy in appearance, the latest being those for 1899

MINERAL PRODUCTION OF RUSSIA. (a) (IN METRIC TONS AND DOLLARS.)

Year.	Asbestos.		Asphaltum.		Chrome Iron Ore.		Coal.		Cobalt Glance.	Copper.		Gold—Kg.	
1895	1,131	$6,800	18,783	$143,542	21,013	$51,316	9,099,476	12,150,400	3	5,854	$1,429,516	41,097	$18,812,998
1896	1,274	7,666	22,192	145,428	6,682	16,316	9,377,551	13,198,424	4	5,832	1,424,076	37,199	16,845,122
1897	1,022	37,444	22,252	184,616	13,433	32,804	11,203,738	15,578,184	3	6,940	1,961,539	38,198	17,255,532
1898	1,665	60,600	12,018	128,176	15,467	37,600	12,307,450	17,148,000	3	7,290	2,138,531	38,830	17,260,141
1899	2,693	97,342	23,081	170,380	19,146	46,742	14,274,361	22,801,400	4	7,533	2,692,800	38,935	17,415,522

Year.	Graphite.		Iron, Cast.		Kaolin.		Lead.		Manganese Ore.		Petroleum.		Phosphorites.	
1895	...	.....	1,452,337	$22,312,800	25,330	101,200	412	$20,000	203,081	$366,522	7,056,330	11,490,800	6,327	$18,682
1896	...	.....	1,620,812	25,815,436	6,099	24,575	262	12,775	208,025	896,000	7,105,768	12,588,860	3,776	11,065
1897	98	.....	1,880,135	31,636,289	5,036	20,244	450	25,285	370,190	1,102,124	7,831,254	14,623,058	5,917	22,139
1898	29	.....	2,241,290	40,478,800	6,648	30,320	241	13,560	329,276	633,031	9,002,190	19,860,631	1,870	4,784
1899	...	.....	2,708,749	48,460,000	7,466	34,050	322	18,079	659,301	1,096,000	9,809,105	34,607,306	16,863	58,640

Year.	Platinum—Kg.		Pyrites.		Quicksilver		Salt.		Silver—Kg.		Sodium Sulphate.	
1895	4,406	$868,960	11,042	$31,200	434	$871,000	1,540,194	$2,388,743	7,878	$229,068	4,207	$15,612
1896	4,930	1,063,600	11,550	32,435	491	482,058	1,346,247	2,079,286	7,813	235,172	5,198	9,600
1897	5,602	1,238,040	19,380	54,426	616	541,440	1,551,894	2,711,077	4,788	172,561	7,280	13,352
1898	6,011	1,439,912	24,570	68,800	362	321,754	1,505,600	2,566,906	5,143	182,500	5,045	9,216
1899	5,962	1,754,480	23,251	57,240	362	321,814	1,681,362	2,767,168	4,422	168,082	7,466	10,893

Year.	Sulphur.		Tin.		Zinc.	
1895	190	$2,816	8	$5,068	5,029	$360,000
1896	437	5,339	2	476	6,257	458,369
1897	574	11,917	2	476	5,868	549,114
1898	1,018	21,244	..	.....	5,664	531,124
1899	451	9,412	..	.....	6,326	575,708

(a) From the Russian official mining report "Sbornik Statisticheskekh Svedenie o Gornozavodskoi Promyshlennostye Rossie v Zavodskom Godu," St. Petersburg. (b) In the Russian reports the quantities are stated in poods and the values in silver rubles. In making the reductions the following relations were employed: 1 pood = ·01638 metric ton; 1 silver ruble = 40 cents.

MINERAL IMPORTS OF RUSSIA. (*a*) (IN METRIC TONS AND DOLLARS.)

(1 pood = ·01638 metric ton; 1 ruble = 40 cents.)

Year.	Asbestos.		Asbestos Manufactures		Asphalt Rock.		Barytes and Witherite.		Clay, Bauxite and Talc.		Coal.		Coke.	
1895..	107	$8,186	241	$58,898	566	$3,465	7,703	$65,297	55,212	$327,338	1,984,289	$5,298,392	310,118	$961,475
1896..	137	5,510	378	85,432	947	8,183	7,053	56,528	e64,135	419,564	1,979,649	5,439,378	364,427	1,146,668
1897..	122	6,593	514	98,829	737	7,392	7,826	73,080	66,980	346,115	2,122,361	4,188,089	399,909	1,675,072
1898..	246	11,073	536	90,676	835	6,785	7,210	69,164	65,716	371,211	2,532,687	4,907,490	458,247	2,078,747
1899..	222	16,226	598	94,636	418	3,920	7,376	66,846	74,851	313,088	3,896,806	9,754,737	573,777	2,512,848

Year.	Copper and Alloys.		Copper and Brass Manufactures.		Glauber Salts.		Gold Bars and Coin.	Iron. Castings.		Iron. Pig.	
1895.....	11,679	$2,725,159	*d*1,598	1,045,372	3,308	$79,863	.....	4,799	$602,644	127,202	$2,227,129
1896.....	15,726	3,997,911	*d*1,601	1,100,247	3,619	78,067	.....	7,810	759,814	75,817	1,454,995
1897.....	13,590	2,818,348	*d*1,947	1,159,106	4,550	90,664	.....	10,280	876,949	98,409	1,857,485
1898.....	15,167	2,841,423	*d*2,369	1,408,894	5,208	63,885	$40,369,200	13,490	1,061,521	86,486	919,750
1899.....	12,355	3,236,735	*d*2,367	1,494,547	3,440	43,683	32,868,400	15,699	1,469,066	136,782	1,702,070

Year.	Iron—*Continued.* Tin Plate.		All Other.		Iron and Steel Manufactures.		Steel, All Kinds.		Lead.		Magnesite.	
1895....	30,489	$2,194,164	218,985	$10,182,897	20,214	$3,205,413	52,523	$3,008,229	29,556	$1,820,843	1,127	$20,094
1896....	23,144	1,707,983	274,288	12,787,963	26,989	3,771,949	72,509	3,981,378	31,398	1,730,550	1,424	5,510
1897....	2,717	146,557	308,345	11,668,788	26,586	3,636,605	87,413	4,201,118	31,336	1,496,581	2,895	23,418
1898....	536	46,370	301,518	8,963,712	27,337	3,934,933	73,468	2,850,043	29,402	1,415,446	4,877	42,948
1899....	840	59,660	268,309	8,176,359	29,264	4,567,398	56,473	3,629,075	36,306	2,089,089	6,848	77,185

Year.	Mica—Kg.		Naphtha, Crude.	Oil, Kerosene, Benzine, etc.		Ores, Except Graphite.		Other Metals, Manufactures of.		Phosphorites.		Pyrites.	
1895..	2,407	$917	(*b*)	537	$44,494	1,534	$19,800	12,370	$3,374,097	(*b*)	.....	22,410	$241,398
1896..	3,047	1,301	8	120	7,084	21,468	58,008	4,858	1,987,570	18,156	$176,868	20,631	149,589
1897..	(*b*)	.....	48	1,811	57,961	21,887	59,619	.....	.....	(*b*)	.....	33,733	157,396
1898..	4,882	1,811	(*b*)	244	21,242	24,015	51,046	13,088	3,486,218	(*b*)	.....	41,127	196,650
1899..	(*b*)	.....	167	1,719	156,280	24,461	54,673	1,430	1,487,554	5,991	14,098	44,821	241,966

Year.	Quicksilver.		Salt.		Saltpeter, Chile.		Salts, Stassfurt.		Silver.	Strontianite and Celestite.		Sulphur.	
1895.....	7	$6,996	10,332	$57,400	12,315	$294,788	4,463	$41,088	.....	34	$1,118	19,595	$233,233
1896.....	15	10,499	10,213	62,492	18,337	414,770	5,553	51,250	.....	216	12,690	19,552	227,498
1897.....	10	6,267	8,467	46,710	12,998	241,360	5,491	40,322	.....	881	10,676	20,715	258,160
1898.....	6	4,216	10,128	54,645	13,712	275,939	5,414	44,240	$12,296,400	143	1,710	18,925	241,827
1899.....	6	5,642	8,849	46,822	15,371	347,866	7,558	46,755	.....	404	3,823	22,473	511,450

Year.	Tar, Asphaltic Mastic, etc.		Tin.		Zinc. Ingot and Sheet.	
1895.....	2,721	$77,668	3,417	$705,597	9,194	$962,106
1896.....	3,011	89,810	4,481	841,436	7,516	766,164
1897.....	6,841	116,869	3,938	808,947	9,546	640,755
1898.....	10,340	170,845	4,191	1,057,406	11,018	688,176
1899.....	13,134	231,858	3,830	1,555,081	11,024	879,572

(*a*) From the Russian official report "Sbornik Statisticheskekh Svedenie o Gornozavodskoi Promyshlennostye Rossie v Zavodskom Godu," St. Petersburg. (*b*) Not reported. (*d*) Includes bronze manufactures. (*e*) Represents clay used for furnaces.

MINERAL EXPORTS OF RUSSIA. (*a*) (IN METRIC TONS AND DOLLARS.)

(1 pood = ·01638 metric ton; 1 ruble = 40 cents.)

Year.	Bronze and Manufactures.	Clay, Bauxite and Talc.		Coal.		Copper and Alloys.		Copper and Brass Manufactures.		Gold Coin and Bullion.
1895..	$10,290	166	$1,227	7,544	$20,870	47	12,154	.....	$ 86,146	.....
1896..	5,709	1,522	3,542	16,566	25,190	31	8,229	129	62,064	.....
1897..	.....	2,050	4,412	33,142	51,879	29	9,353	.....	120,400	.....
1898..	.....	2,014	3,771	48,034	69,140	13	3,801	246	114,582	$143,200
1899..	.....	1,981	2,555	13,238	36,795	12	2,178	.....	107,418	20,394

Year.	Iron.						Manganese Ore.		Metals, Other		Naphtha.			
	Castings.		Pig.		All Other.						Crude.		Residuum.	
1895..	298	$30,070	192	$7,040	2,312	$117,207	146,840	$1,194,035	202	$30,308	9,266	$22,856	54,658	$408,076
1896..	429	39,001	184	7,950	4,534	239,499	165,600	1,215,399	127	12,150	2,942	40,514	54,451	449,876
1897..	547	60,191	238	6 708	4,150	184,139	187,396	1,188,824	(c)	.....	9,605	47,576	62.945	565,210
1898..	384	29,487	184	4,628	2,655	139,054	245,081	1,235,355	178	44,524	8,671	44,540	54,395	451,300
1899..	735	68,828	122	3,934	4,028	212,000	395,000	2,945,408	117	13,223	4,879	24,828	61,787	549,926

Year.	Oil, Kerosene, Benzine, etc.		Ores of Metals and Minerals, Except Graphite.		Paraffin.		Phosphorites.		Platinum, Crude—Kg.		Quicksilver.	
1895..	709,406	$5,642.097	432	$10,260	b1	$370	10,918	$134,886	4,599	$778,000	140	$164,398
1896..	845,751	8,129,780	20,626	40,071	b93	3,746	8,840	107,808	4,700	777,900	490	393,629
1897..	917,216	9,507,619	16,690	40,874	b 740	15,516	2,917	36,369	4,767	700,780	643	575,409
1898..	1,115,106	10,555,454	15,864	118,332	b5,197	52,505	1,694	26,465	4,475	825,600	357	274,784
1899..	1,390,313	11,771,924	13,688	63,301	b8	699	5,629	70,760	3,423	1,142,782	338	247,494

Year.	Salt.		Silver.	Slags.		Steel.		Zinc.			
								Ore.		Ingot and Sheet.	
1895..	7,023	$17.790	.....	5,178	$11,334	167	$14,855	208	$2,820	1·0	$446
1896..	6,814	16,461	.....	5,606	11,274	173	15,338	194	4,390	3·5	264
1897..	9,032	21,668	.....	9,702	22,447	160	17,579	.....	.....	12·4	1,552
1898..	9,534	25,008	$1,804,000	17,088	40,878	312	28,939	.....	.....	76·9	5,808
1899..	7,852	29,151	.....	13,995	28,359	174	16,242	362	4,849	56·0	3,327

(a) From the Russian official report "Sbornik Statisticheskekh Svedenie o Gornozavodskoi Promyshlennosty Rossie v Zavodskom Godu," St. Petersburg. (b) Includes vaseline. (c) Not reported.

SPAIN.

THE official statistics of mineral production, imports and exports, are summarized in the following tables:

MINERAL AND METALLURGICAL PRODUCTION OF SPAIN. (*a*) (IN METRIC TONS AND DOLLARS; $1 = 5 pesetas.)

Year.	Aluminous Earths.		Antimony Ore.		Arsenic Sulphide.		Asphalt, Refined.		Asphalt Rock.		Barytes.		Cement, Hydraulic.	
1896....	320	$1,600	54	$1,395	271	$27,100	1,285	$16,705	1,117	$2,234	345	$1,720	130,738	$281,144
1897....	409	2,046	354	6,718	244	29,256	1,878	22,532	1,656	3,312	429	2,449	159,439	325,202
1898....	505	2,525	130	2,149	111	13,320	2,354	29,626	2,383	4,772	364	2,074	164,862	358,501
1899....	685	3,225	50	1,560	101	12,156	2,646	34,068	2,542	5,144	887	3,071	165,645	363,441
1900....	420	2,100	30	900	150	18,036	2,331	31,602	4,193	8,632	833	1,568	185,811	422,725

Year.	Coal.								Cobalt Ore.		Coke.	
	Anthracite.		Bituminous.		Briquettes.		Lignite.					
1896.....	14,895	$26,788	1,832,947	$2,806,654	343,432	$1,373,061	55,413	$60,261	18	$1,800	288,523	$1,202,716
1897.....	8,758	15,745	2,010,960	3,409,636	332,272	1,318,532	54,232	54,027	13	3,400	755,394	3,167,416
1898.....	20,105	36,190	2,414,127	4,147,333	369,418	1,277,425	66,422	93,310	(*b*)	.....	768,151	3,211,300
1899.....	34,842	98,256	2,565,437	4,780,114	348,838	1,216,562	70,901	78,630	(*b*)	.....	341,443	1,311,816
1900.....	68,427	238,015	2,514,545	4,700,324	341,156	1,585,691	91,133	101,467	(*b*)	.....	381,000	2,716,706

Year.	Copper.						Copper Ore.					
	Fine.		In Matte.		In Precipitate.		Argentiferous.		Copper and Cobalt.		Pyrites.	
1896.....	6	$1,200	16,378	$982,702	29,873	$4,155,204	*c*157,365	$146,596	992	$23,808	2,200,919	$2,205,843
1897.....	7	1,400	16,120	967,210	29,652	4,138,725	*c*18,488	35,922	(*b*)	.....	2,161,182	2,124,993
1898.....	593	118,623	16,024	961,438	29,703	4,158,418	203	1,831	(*b*)	.....	2,299,444	2,735,261
1899.....	4	921	15,775	946,506	41,927	5,859,545	1,103	16,909	(*b*)	.....	2,443,044	2,985,001
1900.....	5	1,919	18,159	1,452,728	29,652	7,279,259	2,006	21,047	(*b*)	.....	2,714,714	9,246,013

Year.	Fluorspar.		Gold and Silver Ore.		Graphite.		Iron and Steel.					
							Forged Iron.		Pig Iron.		Steel.	
1896....	3	$45	854	$3,056	(*b*)	.....	53,793	$2,224,443	100,786	$1,481,162	68,126	$2,666,843
1897....	2	36	2,456	9,878	(*b*)	.....	80,894	3,190,139	146,940	2,267,403	66,007	2,873,930
1898....	5	75	555	2,165	10	$18	65,900	2,826,743	113,492	2,059,232	50,362	2,332,019
1899....	310	750	*f*1,110	7,060	(*b*)	.....	40,332	1,120,514	113,071	2,011,536	112,982	4,138,317
1900....	4	60	*f*1,300	7,800	(*b*)	.....	54,307	1,920,942	91,126	2,671,978	144,355	4,831,309

Year.	Iron Ore.				Kaolin. (China Clay.)		Lead.			
	Argentiferous.		Non-Argentiferous.				Argentiferous.		Non-Argentiferous.	
1896.....	3,581	$3,581	6,762,582	$5,013,404	1,240	$2,446	84,802	$5,808,313	82,215	$4,386,544
1897.....	5,539	19,347	7,419,768	5,457,327	6,294	6,717	91,258	6,312,109	75,112	4,343,187
1898.....	24,190	68,216	7,197,047	6,232,484	5,445	5,518	88,981	6,026,450	78,370	5,188,394
1899.....	17,139	25,051	9,397,733	8,600,211	2,790	7,540	70,874	4,895,323	91,739	7,450,466
1900.....	26,848	66,661	8,675,749	7,598,921	3,794	8,084	74,341	6,124,426	98,189	8,676,061

Year.	Lead Ore.				Manganese Ore.		Mineral Waters.		Nickel Ore.	
	Argentiferous.		Non-Argentiferous.							
1896.....	182,565	$6,121,173	104,160	$1,884,807	88,265	$53,732	15,738,142	$92,485	100	$880
1897.....	186,692	6,735,013	110,469	2,058,611	100,566	186,250	16,180,585	115,874	(b)	.....
1898.....	244,068	8,023,772	150,472	4,948,056	102,228	343,045	15,610,222	122,265	(b)	.....
1899.....	184,906	7,624,507	123,753	4,774,408	104,974	353,088	19,770,137	113,907	(b)	.....
1900.....	182,016	6,875,290	131,437	5,449,629	112,897	380,321	19,289,928	144,744	(b)	.....

Year.	Ocher.		Phosphorites.		Pyrites.		Pyrites. (Arsenical)		Quicksilver.		Quicksilver Ore.	
1896.....	212	$850	770	$3,080	100,000	$50,000	(b)	.....	1,524	$1,287,144	34,959	$1,877,396
1897.....	200	800	2,084	16,672	100,000	50,000	(b)	.....	1,728	1,564,338	32,378	1,328,443
1898.....	200	800	4,500	45,008	70,265	35,135	230	$575	1,691	1,593,921	31,361	1,282,024
1899.....	100	400	3,510	35,100	107,386	105,182	(b)	.....	1,361	1,481,229	32,144	1,274,606
1900.....	58	233	4,170	18,590	84,638	24,247	515	515	1,095	1,479,338	30,216	1,104,287

Year.	Salt.		Silver—Kg.		Silver Ore.		Soapstone.		Sulphur.	
1896.....	521,751	$1,153,880	64,554	$1,507,441	1,230	$129,943	756	$1,166	1,800	$36,004
1897.....	508,606	1,159,294	71,168	1,555,636	992	101,797	3,601	21,341	3,500	70,000
1898.....	479,358	1,025,682	76,295	1,835,156	767	106,094	2,613	14,504	3,100	62,400
1899.....	598,108	1,091,133	68,409	2,161,531	764	78,721	4,844	26,622	1,100	21,350
1900.....	450,041	834,535	140,457	3,651,800	742	131,068	8,109	46,004	750	18,000

Year.	Sulphur, Crude Rock.		Tin Ore.		Topaz of Hinojosa. Kg.		Tungsten Ore		Zinc.		
									Calamine, Calcined.	Ore.	
1896.....	26,204	$45,433	d2,348	$5,908	80	$12,860	31	$1,560	23,108	64,888	$407,670
1897.....	18,845	32,588	d2,378	5,795	44	751	10	309	(b)	73,848	363,846
1898.....	e105,757	198,138	4	408	90	1,454	377	5,325	(b)	99,836	991,396
1899.....	58,922	102,150	57	8,450	44	751	151	14,142	(b)	119,710	1,208,987
1900.....	64,364	109,947	47	7,163	95	751	1,958	100,382	(b)	86,158	617,651

Year.	Zinc.			
	Sheet.		Slabs.	
1896.....	2,648	$405,175	3,485	$390,286
1897.....	2,337	378,594	3,907	445,212
1898.....	1,731	322,040	4,300	602,000
1899.....	2,084	387,624	4,100	574,000
1900.....	2,756	512,616	2,855	399,784

(a) Figures for 1897 are from the *Reports of the Comisión Ejecutiva de Estadística Minera*. The figures for 1895, 1896 and 1898, are from the official *Reports of the Junta Superior Facultativa de Minas*, Madrid. There was also produced in 1896, lead and zinc ores, 400 metric tons, $400; in 1897, gold ore, 450 metric tons, $1,850; lead and zinc ores, 40 metric tons, $40; in 1898, lead and zinc ore, 38 tons, $38; gold, $2,338. (b) Not reported. (c) Represents non-argentiferous copper ore. (d) Undressed ore. (e) 70,814 tons, $152,309, of this product is the contents of copper pyrites from Huelva. (f) Gold ore only.

MINERAL IMPORTS OF SPAIN. (a) (IN METRIC TONS AND DOLLARS; $1 = 5 pesetas.)

Year.	Asphalt and Pitch.		Alkaline Carbonates		Coal.		Coke. (b)		Gold Bars—Kg.	
1896.....	35,401	$566,427	27,014	$1,188,641	1,447,345	$8,[illegible]68	234,033	$1,115,516	337	$235,900
1897.....	23,324	368,700	28,428	1,210,426	1,633,333	8,[illegible]95	214,763	1,159,731	268	187,600
1898.....	28,720	459,528	26,574	1,169,245	1,224,345	7,[illegible]73	196,224	1,177,346	2	1,440
1899.....	37,827	605,231	34,805	1,395,614	1,555,800	9,131,802	208,780	1,252,735	10,210	7,555,400
1900.....	29,983	479,738	31,463	1,286,519	1,794,119	14,352,956	197,516	1,580,134	(c)	.....

Year.	Gold Coin		Iron, Pig.		Iron, Bar.		Iron and Steel, Forged.		Petroleum, Crude.		Silver Bars. Kg.	
1896.....	$16,231	8,577	$120,087	13,861	$607,539	26,463	$1,398,827	34,427	$1,233,345	5,576	$150,812
1897.....	12,149	1,855	25,972	13,558	571,043	24,037	1,472,690	34,972	1,259,011	243,540	6,341,894
1898.....	(c)	1,575	28,372	(c)	.....	5,164	267,159	32,731	1,505,671	153,475	4,143,825
1899.....	(c)	2,267	40,793	(c)	.....	5,687	250,119	23,522	1,082,019	46,504	1,209,104
1900.....	(c)	4,717	113,227	(c)	.....	5,404	230,465	42,840	1,718,619	(c)	.....

Year.	Silver Coin.	Sodium Nitrate.		Sulphur.		Tin Plate.		Tin Ingots.	
1896.....	$20,190,400	26,841	$1,610,495	7,744	$185,870	1,071	$89,977	1,080	$432,001
1897.....	22,325,312	34,862	2,091,729	5,310	128,883	565	46,098	928	369,359
1898.....	(c)	38,822	2,146,035	5,665	158,621	658	52,237	833	350,028
1899.....	(c)	56,408	3,158,871	6,395	178,791	1,661	132,859	987	393,492
1900.....	(c)	118,105	4,724,294	7,634	244,290	914	63,920	1,143	914,789

(a) The figures for 1898 and 1899 are from the *Anuario de la Mineria Metalurgia y Electricidad de España*, while those for the years 1896 and 1897 are from the *Revista Minera*, Madrid, Feb. 18, 1898. (b) In terms of coal. (c) Not reported.

MINERAL EXPORTS OF SPAIN. (a) (IN METRIC TONS AND DOLLARS; $1 = 5 pesetas.)

Year.	Antimony Ore.		Cement, Hydraulic		Coal.		Copper Ore.		Copper, in Matte and Precipitate.	
1896.....	119	$7,190	(b)	.....	4,293	$23,205	629,546	$5,065,918	46,417	$4,385,213
1897.....	20	1,176	(b)	.....	2,539	13,900	822,570	6,613,482	51,487	7,373,928
1898.....	50	2,962	(b)	.....	2,643	14,277	899,238	6,474,516	49,570	7,466,956
1899.....	92	5,537	3,502	$24,521	8,073	45,518	948,917	6,852,205	44,008	6,638,755
1900.....	23	1,362	2,499	14,997	8,588	56,678	1,029,141	7,409,812	48,676	7,898,468

Year.	Iron Ore.		Iron Pyrites.		Iron and Steel.		Lead Ore.			
							Argentiferous.		Non-Argentiferous.	
1896.....	6,299,257	$11,320,670	464,882	$920,977	23,085	$233,270	c6,270	$392,668	(b)	.....
1897.....	6,884,244	13,180,064	217,545	569,287	43,612	610,776	c8,267	462,595	(b)	.....
1898.....	6,558,060	14,427,736	256,341	615,218	46,127	830,291	7,191	410,178	(b)	.....
1899.....	8,606,558	18,934,429	319,285	766,881	40,879	735,826	8,019	497,168	2,334	$102,961
1900.....	7,823,270	18,775,848	356,018	854,445	23,554	626,986	4,971	239,294	1,109	51,004

Year.	Lead, Pig.				Manganese Ore.		Quicksilver.		Salt.	
	Argentiferous.		Non-Argentiferous.							
1896.....	d166,124	$9,500,935	(b)	.....	87,835	$627,620	1,559	$1,746,154	254,752	$764,257
1897.....	d171,774	10 122,220	(b)	.....	95,756	1,091,021	1,742	1,436,293	235,871	707,616
1898.....	d178,517	11,340,015	(b)	.....	139,050	1,597,706	1,741	1,880,703	219,670	659,099
1899.....	d161,098	9,967,370	(b)	.....	139,352	1,588,815	3,221	3,478,789	331,081	993,212
1900.....	d153,939	11,490,632	(b)	.....	131,450	1,445,945	1,101	1,188,646	205,561	411,122

Year.	Silver—Coin, Jewelry, etc.		Soapstone.		Sulphur.		Tin.		Zinc.		Zinc Ore.	
1896....	(b)	.....	(b)	.....	(b)	.....	(b)	.....	3,560	$356,060	36,656	$308,272
1897....	(b)	.....	(b)	.....	(b)	.....	(b)	.....	2,170	239,716	41,040	353,121
1898....	(b)	.....	(b)	.....	(b)	.....	(b)	.....	4,553	500,791	65,573	697,479
1899....	(b)	.....	2,427	$77,663	1,891	$52,968	26	$10,595	2,390	260,899	95,068	989,671
1900 ...	133	$4,218,649	(b)	.....	7	251	30	20,692	2,081	228,832	61,199	646,006

(a) From the *Anuario de la Mineria Metalurgia y Electricidad de España*, Madrid. (b) Not reported. (c) Includes non-argentiferous lead ore. (d) Includes non-argentiferous.

SWEDEN.

THE official statistics of mineral production, imports and exports are summarized as follows:

MINERAL PRODUCTION OF SWEDEN. (*a*) (IN METRIC TONS.)

Year.	Alum.		Clay (Fire).		Coal.		Cobalt Oxi. Kg.		Copper.		Copperas.		Copper Ore.		Copper Sulphate.	
1896..	334	$9,849	120,426	(*c*)	225,848	$435,891	(*c*)	.....	249	$56,724	191	$2,463	24,351	$83,125	1,506	$105,300
1897..	131	3,826	112,283	(*c*)	234,343	434,710	700	$2,457	289	68,645	282	3,235	25,207	92,712	1,315	99,860
1898..	153	4,543	131,391	(*c*)	236,277	465,936	3,001	10,125	235	59,699	124	1,783	23,335	99,749	1,165	78,840
1899..	164	4,917	129,875	(*c*)	239,344	485,239	1,345	4,536	179	60,028	105	1,483	22,894	110,463	1,267	108,000
1900..	167	4,402	160,585	62,290	252,320	550,721	*Nil.*	.....	136	45,880	183	2,306	22,725	92,678	1,265	125,000

Year.	Feldspar.		Gold—Kg.		Gold Ore.		Iron.				Iron Ore.		Iron Ore. (Bog.)	
							Pig.		Bloom.					
1896..	12,789	$39,417	114·5	$76,806	736	$5,913	494,418	$8,283,999	188,396	$4,772,077	2,089,019	$2,518,175	925	(*c*)
1897..	19,296	58,992	113·3	75,517	1,692	9,214	538,197	9,467,855	189,633	5,045,705	2,086,119	2,700,639	1,047	(*c*)
1898..	20,737	64,572	125·9	106,318	2,136	6,136	531,766	9,414,123	198,923	5,407,843	2,302,546	2,969,986	398	(*c*)
1899..	16,017	50,041	106·2	71,081	*Nil.*	.....	497,727	9,823,735	195,331	5,866,026	2,434,606	3,627,517	594	(*c*)
1900..	15,228	46,457	88·5	55,224	*Nil.*	.....	526,868	11,988,097	188,455	6,324,423	2,607,925	3,738,237	1,575	2,251

Year.	Iron and Steel Bars, Rods, Sheets, etc.		Lead.		Lead Ore.		Manganese Ore.		Pyrites.		Silver. Kg.	
1896	308,132	$12,036,504	1,530	$76,083	14	$491	2,056	$7,251	1,009	$3,914	2,092	$44,263
1897	304,537	12,624,486	1,480	76,876	99	3,240	2,749	12,810	517	1,496	2,218	41,471
1898	299,846	11,943,458	1,559	102,464	50	1,620	2,358	11,142	396	1,037	2,053	38,897
1899	338,999	14,223,434	1,606	106,846	35	1,134	2,622	12,080	150	364	2,290	43,411
1900	324,604	14,790,197	1,424	105,697	85	2,950	2,651	12,294	179	395	1,927	35,831

Year.	Silver and Lead Ore.		Steel.						Sulphur.		Zinc Ore		Zinc Ore. (Calcined.)	
			Bessemer.		Crucible.		Martin.							
1896....	15,381	$75,252	114,120	$3,091,384	604	$53,318	142,301	$3,851,974	77	(*c*)	44,041	$330,738	23,000	$322,920
1897....	10,068	63,123	107,679	3,091,109	691	73,540	165,836	4,652,524	(*c*)	.....	56,636	494,742	21,583	258,420
1898....	6,743	53,631	102,254	2,896,079	1,018	106,318	160,706	4,512,212	50	$1,620	61,627	603,647	25,250	443,137
1899....	5,730	60,070	91,898	2,710,926	1,225	126,765	179,357	5,549,606	(*c*)	.....	65,159	743,869	24,200	516,186
1900....	5,300	65,534	91,065	2,968,514	1,121	102,893	207,418	6,768,626	70	1,750	61,034	477,034	26,772	401,580

(*a*) From *Bidrag till Sveriges Officiela Statistik, Bergshandteringen.* In 1899 there was also an output of 500 tons of graphite ore valued at $540. (*c*) Not reported.

MINERAL IMPORTS OF SWEDEN. (*a*) (IN METRIC TONS AND DOLLARS; 1 krone = 27 cents.)

Year.	Alum.		Aluminum Sulphate.		Ammonium.										Antimony Crude.	
					Carbonate.		Chloride.		Hydrate.		Nitrate.		Sulphate.			
1896	75	$2,223	629	$8,494	79	$17,114	88	$18,983	81	$7,279	11	$4,609	88	$7,152	63	$11,822
1897..	103	3,072	733	9,896	109	20,516	110	20,873	59	5,605	42	9,013	67	4,536	58	11,053
1898..	136	4,036	968	13,074	99	18,723	101	19,168	105	9,886	12	2,565	81	5,477	53	9,936
1899..	158	4,688	866	11,699	89	16,900	112	21,164	110	10,391	12	2,561	181	12,221	59	11,170
1900..	133	3,948	1,197	16,165	141	13,329	99	18,675	100	18,923	5	1,129	227	15,297	85	16,151

Year.	Arsenious Acid.		Asbestos. (c)		Asphalt. (d)		Barytes.		Borax.		Boric Acid.		Bromine and Bromides of Potassium and Sodium. Kg.	
1896....	33	$3,587	116	$31,407	4,092	$44,190	298	$16,084	128	$17,243	73	$11,807	4,334	$3,511
1897....	33	3,523	119	32,151	5,458	58,947	270	14,595	175	18,952	56	9,006	5,549	4,495
1898....	33	4,390	112	30,359	5,409	58,420	299	16,140	196	21,148	75	12,071	5,401	5,697
1899....	12	1,642	567	153,193	6,286	67,898	292	15,812	190	20,529	65	10,596	4,914	5,175
1900....	22	3,029	763	206,145	5,676	61,305	441	23,795	194	20,950	66	10,743	6,084	6,406

Year.	Cement.		Chalk. White, Unground. *Hektoliters.*		Chalk. Other Kinds. (e)		Chemico-Technical Preparations N.E.S. (f)	Chloride of Lime.		Clay Products. Brick & Tiles.		Clay.	Porcelain.	
1896....	2,901	$27,411	6,148	$664	146	$1,143	$87,885	1,600	$69,116	$196,482		$79,655	227	$247,878
1897....	1,826	17,259	14,368	1,552	142	1,069	100,021	1,676	72,398	263,379		80,010	362	273,784
1898....	1,656	15,653	7,016	758	308	1,813	115,499	1,668	72,048	359,374		109,738	298	218,573
1899....	1,363	12,877	16,079	1,737	86	1,402	121,878	2,402	103,777	267,299		95,592	346	244,637
1900....	1,941	18,339	12,059	1,309	64	1,160	180,328	2,943	127,146	328,263		138,655	382	267,992

Year.	Coal. (g)		Copper, and Copper in Alloys and Metals.		Copper & Iron Sulphates.	Emery.		Glass and Glassware. (h)		Gold Bars, and Gold M'f'res. Kg.		Gold Coin.	Graphite.	
1896..	1,991,760	$8,402,736	4,037	$947,930	$11,026	104	$14,004	2,477	$447,353	1,161	$107,001	$608	135	$7,811
1897..	2,240,247	9,829,086	4,944	1,156,202	5,805	128	17,296	1,618	507,491	4,267	2,066,848	948	158	8,519
1898..	2,392,451	12,112,784	5,227	1,220,805	6,512	131	17,649	2,560	551,169	3,998	1,875,585	2,896	167	9,008
1899..	3,047,618	16,457,135	4,740	1,105,524	11,202	125	16,902	2,213	532,609	362	287,075	9,774	162	8,729
1900..	3,083,885	21,502,660	4,745	1,281,949	4,963	136	18,399	1,728	461,291	3,365	2,282,429	98,905	213	11,486

Year	Gypsum. (j)		Iron and Steel. Crude.		Iron and Steel. Manufactures.	Lead, Crude.		Lime. *Hektoliters.* (k)		Litharge.		Nitric Acid.	
1896....	4,940	$37,274	34,549	$878,383	$3,703,338	1,911	$180,749	7,768	$2,619	150	$20,202	32	$2,574
1897....	7,260	75,270	89,606	1,420,175	3,785,043	2,098	206,076	20,050	7,389	199	26,925	41	3,295
1898....	7,979	66,187	76,832	1,326,910	4,641,613	2,139	207,342	23,079	8,724	160	21,592	34	3,252
1899....	6,457	65,486	68,909	1,282,713	5,867,895	2,125	215,996	34,343	10,732	177	23,918	77	7,308
1900....	6,794	69,715	82,957	1,906,169	5,152,371	2,067	213,786	25,047	10,144	148	19,974	66	6,276

Year.	Phosphorus. Kg.		Platinum. Kg.		Potassium. Chloride.		Potassium. Cyanide. Kg.		Potassium. Hydrate. (Caustic.)		Potassium. Oxide.		Quicksilver. Kg.	
1896....	52,482	$63,766	34	$6,426	241	$45,508	2,122	$1,719	285	$92,217	1,933	$182,688	5,194	$5,890
1897....	57,972	70,436	63	11,907	363	58,817	2,922	2,367	1,381	410,247	1,482	135,370	3,125	3,544
1898....	66,466	80,756	49	9,261	259	28,006	2,604	1,757	1,451	431,080	1,112	105,119	2,631	2,983
1899....	59,989	72,897	59	11,151	225	36,466	2,813	1,561	1,266	376,029	1,231	116,293	4,210	4,774
1900....	67,557	82,082	99	18,711	364	58,945	2,221	1,662	1,915	568,627	1,257	118,740	3,629	4,115

Year.	Salt. Common.		Salt. Refined.		Sand.	Silver and Man'factures Kg.		Silver Coin.	Sodium Salts. Carbonate.		Sodium Salts. Hydrate.	
1896....	94,629	$318,011	3,673	$148,755	$30,428	7,375	$217,141	$204,691	11,425	$215,932	908	$49,051
1897....	87,050	411,548	3,055	148,479	19,509	20,557	473,801	136,823	14,625	276,417	625	33,764
1898....	85,246	403,380	2,188	106,332	29,169	21,696	442,622	191,766	11,917	225,230	575	31,064
1899....	98,417	410,917	3,166	153,884	35,848	11,565	904,825	156,707	13,323	251,806	929	50,151
1900....	70,302	313,058	3,098	150,547	36,054	11,559	909,820	62,315	12,680	239,658	1,038	56,083

Year.	Sodium Salts.—*Continued.* Nitrate. (l)		Sodium Salts.—*Continued.* Sulphate. (i)		Stone. (m)	Sulphur.		Sulphuric Acid.		Tin. (Crude.)		Tin and Lead Ashes.	
1896.....	12,518	$565,900	8,486	$229,121	$122,525	11,369	$276,265	615	$12,455	551	$170,307	11	$12,182
1897.....	12,531	602,709	11,384	153,683	227,476	9,723	236,269	1,418	28,709	541	196,478	16	28,709
1898.....	15,419	685,657	11,544	172,435	103,260	10,837	263,341	1,742	35,278	595	224,890	25	27,455
1899.....	15,006	708,150	15,140	204,384	98,648	13,505	328,165	2,558	51,797	486	295,458	8	8,704
1900.....	14,245	673,072	15,590	211,972	94,188	20,152	489,683	2,472	50,052	680	408,021	18	19,297

Year.	Tin Ore (Black Tin.)		Tungsten Ore.		Uranium Ore.		Zinc Ore.	
1896	7,786	$1,299,640	44	$6,775	36	$7,500	19,598	$332,225
1897	7,234	1,271,090	127	10,040	20	6,835	18,596	345,770
1898	7,498	1,441,625	331	79,220	26	5,925	23,929	588,920
1899	6,494	2,202,545	96	19,155	7	1,375	28,505	697,410
1900	6,911	2,618,020	9	1,755	42	7,585	25,070	486,030
1901	7,407	.....	21	.....	80	.....	23,967	.....

METALS OBTAINABLE BY SMELTING FROM THE ORES IN THE ABOVE TABLE. (*a*) (IN METRIC TONS AND DOLLARS; £1 = $5.)

Year.	Copper, Fine.		Gold—Kg.		Iron.		Lead.		Silver—Kg.		Tin.		Zinc.	
1896	565	$140,900	42·1	$25,175	4,835,597	$56,877,370	31,311	$1,754,700	8,828	$181,825	4,915	$1,588,390	7,224	$616,200
1897	526	135,480	63·2	35,925	4,942,679	56,973,895	26,988	1,662,890	7,750	143,070	4,524	1,456,630	7,162	634,115
1898	650	177,615	12·3	6,495	4,928,347	61,700,215	25,761	1,664,975	6,575	118,640	4,722	1,729,060	8,711	897,910
1899	647	249,840	103·5	60,480	4,992,468	85,174,370	23,929	1,776,895	5,969	109,710	4,077	2,540,470	8,837	1,100,660
1900	777	299,975	437·6	260,735	4,743,172	97,984,550	24,762	2,094,800	5,964	112,325	4,337	2,939,345	9,214	942,865

(*a*) From *Mineral Statistics of the United Kingdom.* (*b*) Including china clay, potters' clay, and fuller's earth; and for 1896 comprises a large quantity of ordinary brick clay not included in the returns of previous years. (*d*) Bog ore, which is raised in Ireland, is an ore of iron, used principally for purifying gas. (*e*) Not reported. (*f*) Not including chalk. (*g*) Included with granite. (*h*) Statistics not yet available.

Additional products: In 1897: Mica, 5,063 metric tons, $8,635; soapstone, 28 metric tons, $490; nickel ore, 305 metric tons, $1,500. Metals obtainable by smelting in 1897: Aluminum, 315 metric tons, $229,400; nickel, 7½ metric tons, $5,250; sodium, 86 metric tons, $63,750.

MINERAL IMPORTS OF THE UNITED KINGDOM. (*a*) (METRIC TONS AND DOLLARS; £1 = $5.)

Year.	Alkali.		Asphaltum.		Borax.		Brass and Bronze Manufactures.		Chemical Products.	Clay Products, Porcelain and Earthenware.		Coal, Culm and Cinders.		Copper. Man'f'res Unenumerated.
1896	8,949	$480,650	29,069	$394,790	(*b*)	.....	2,075	$1,096,020	$6,922,975	16,444	$4,223,745	16,000	$130,075	$1,243,050
1897	11,557	545,010	44,541	519,080	(*b*)	.....	2,129	1,045,985	6,781,900	17,847	4,523,940	9,605	87,555	1,882,425
1898	12,179	673,180	46,398	685,110	1,255	$77,140	2,357	1,068,330	6,939,150	16,405	4,301,740	11,191	81,550	2,662,400
1899	12,078	669,390	59,073	807,840	3,076	154,075	1,988	919,930	7,478,170	18,341	4,604,100	1,777	16,985	3,406,800
1900	16,360	840,790	53,061	728,355	15,667	777,045	2,335	1,066,180	7,493,120	18,329	4,647,390	10,112	60,770	5,248,255

Year.	Copper.—*Continued.* Ore.		Regulus and Precipitate.		Wrought, Unwrought & Old.		Diamonds—*Carats.*		Glass, All Kinds.	Gold Leaf. *Number.*	
1896	88,732	$2,833,955	92,252	$11,477,545	66,405	$15,013,905	3,527,810	$22,995,880	$12,537,895	70,483,026	$694,265
1897	83,916	2,383,130	90,008	11,378,900	62,055	15,200,790	3,472,916	22,176,300	15,084,555	68,173,400	666,595
1898	91,141	3,291,150	76,201	9,779,790	70,018	17,988,325	3,476,509	22,619,075	16,423,915	63,632,700	634,360
1899	130,611	5,460,735	84,015	12,562,945	60,502	21,572,275	2,730,502	20,597,910	16,044,400	49,108,570	486,430
1900	103,076	5,865,210	89,123	17,587,530	72,223	26,384,295	1,882,673	17,168,180	15,982,460	54,346,025	540,855

Year.	Gold Ore.		Graphite.		Iron. Bar, Angle, Bolt and Rod.		Iron and Steel Mfres	Iron and Steel, Old and Scrap.		Ore.	
1896	2,263	$604,015	13,861	$1,121,195	72,195	$2,852,060	$22,055,335	15,578	$295,555	5,525,320	$18,893,945
1897	1,074	736,415	13,472	1,104,480	69,222	2,697,545	27,894,295	20,735	344,610	6,064,179	22,179,670
1898	1,019	1,393,175	15,113	1,506,805	70,331	2,782,745	33,379,160	24,619	349,230	5,555,889	20,173,210
1899	295	761,755	17,777	2,307,935	74,336	2,880,790	39,527,075	32,427	452,130	7,168,061	26,875,190
1900	(*c*)	1,432,970	14,962	1,733,805	81,436	3,281,165	41,536,105	31,687	559,720	6,398,639	28,195,015

Year.	Iron.—*Continued.* Pig and Puddled.		Steel, Unwrought.		Lead. Ore.		Pig and Sheet.		Manufactures.		Manganese Ore.	
1896	108,152	$2,206,220	17,771	$788,730	57,172	$1,448,245	170,484	$9,298,715	218	$51,895	162,542	$1,844,740
1897	100,531	2,588,430	40,628	1,330,655	32,818	1,001,140	170,121	10,166,500	298	61,150	158,825	1,735,775
1898	162,075	2,688,445	40,875	1,263,025	44,457	1,512,535	197,591	12,606,780	419	66,880	156,390	1,700,555
1899	174,159	3,104,255	78,257	2,170,100	30,263	1,269,560	201,551	14,419,185	241	42,415	261,740	2,927,105
1900	184,049	4,025,495	182,210	6,090,895	21,566	1,095,410	198,416	16,597,870	(*d*)	.....	270,098	3,423,080

Year.	Mica, Sheet.		Mica and Talc.		Paraffine.		Petroleum. *Liters.*		Phosphate Rock.		Painters, Colors and Pigments.
1896....	431	$528,060	1,758	$520,425	36,850	$3,555,250	862,960,772	$18,660,280	295,975	$2,329,655	$4,950,635
1897....	412	554,480	1,688	570,595	39,284	3,375,055	842,920,307	16,676,355	330,335	2,466,060	5,049,225
1898....	517	711,855	1,398	419,095	48,104	4,045,160	829,995,751	18,668,150	334,834	2,499,360	5,619,685
1899....	519	710,630	6,025	701,880	54,712	5,055,335	908,107,248	22,863,945	426,830	3,414,700	5,842,063
1900....	469	633,570	7,952	1080,380	50,033	6,696,355	1,162,454,512	27,872,665	361,309	2,943,490	6,747,800

Year.	Platinum, Wrought and Unwrought. Kg.		Potassium Nitrate.		Pyrites, Iron and Copper.		Quicksilver.		Silver Ore.	Slate.	Sodium Nitrate.	
1896....	1,748	$368,725	17,310	$1,392,420	598,480	$4,998,965	1,604	$1,638,645	$6,488,680	$940,890	108,148	$4,182,760
1897....	2,257	437,385	16,744	1,233,495	633,009	5,104,480	1,862	1,954,405	7,149,210	1,538,660	107,595	4,059,325
1898....	3,389	734,205	13,323	1.016,215	665,544	5,404,415	1,856	1,940,880	5,729,525	1,646,005	132,412	4,864,005
1899....	5,404	1,177,870	12,635	1,022,425	712,393	5,821,335	1,759	2,077,150	5,162,750	1,690,720	163,387	5,348,875
1900....	5,027	1,189,270	12,793	1,074,875	752,605	6,184,205	1,113	1,486,215	5,154,480	1,232,175	143,461	5,777,310

Year.	Stone, Marble, Hewn or Manufactured.		Sulphur.		Tin in Blocks, Ingots, Bars, or Slabs.		Tin Ore.		Zinc, Crude, in Cakes..	
1896....	683,977	$4,141,185	22,990	$470,060	38,989	$11,448,440	4,950	$725,915	77,861	$6,225,065
1897....	752,345	4,592,345	22,811	511,045	27,214	8,118,990	5,345	682,935	70,929	5,946,945
1898....	883,699	5,179,950	19,642	450,155	20,665	6,948,005	5,710	785,285	78,761	7,211,345
1899....	905,432	5,526,265	21,906	508,075	27,608	10,200,910	6,324	1,258,260	71,068	8,316,905
1900....	961,492	5,644,225	22,993	545,240	33,648	21,795,665	7,449	1,879,550	61,504	7,210,160

Year.	Zinc Manufactures.		Zinc Ore.		Ores, Unclassified.		Metals, Unclassified, Wrought, Unwrought, and Old.	
1896.....	21,339	$2,097,185	21,421	$493,170	45,782	$1,289,665	10,695	$2,687,750
1897.....	21,395	2,194,365	25,238	583,345	72,675	1,950,095	16,000	3,678,235
1898.....	21,618	2,390,440	53,945	1,100,705	51,660	1,478,625	14,459	3,545,690
1899.....	21,521	2,969,650	38,143	1,121,870	80,322	1,899,360	13,475	4,095,190
1900.....	22,096	2,798,525	42,755	1,179,250	63,868	1,663,505	16,269	5,517,945

(*a*) *Accounts Relating to Trade and Navigation of the United Kingdom.* (*b*) Not reported. (*c*) Entered by value only in 1900. (*d*) Included with Metals, unclassified, wrought.

MINERAL EXPORTS OF THE UNITED KINGDOM. (*a*) (IN METRIC TONS AND DOLLARS. £1 —$5.)

EXPORTS OF DOMESTIC PRODUCE.

Year.	Alkali.		Ammonium Sulphate.		Brass and Manufactures		Cement.		Chemical Products.	Clay Products Porcelain and Earth'nw.	Coal and Culm.	
1896	245,988	$6,210,865	130,130	$5,807,615	6,070	$2,463,115	359,429	$2,902,085	$11,532,200	$10,847,690	33,474,848	$71,898,560
1897	252,786	6,393,450	155,449	6,298,700	5,718	2,458,370	398,023	3,239,595	11,969,165	8,629,425	35,919,965	77,922,710
1898	191,578	5,033,025	139,806	6,450,155	5,418	2,346,205	381,648	3,052,615	12,577,815	8,253,640	35,619,365	85,779,115
1899	193,492	5,158,115	142,577	7,781,860	5,797	2,815,835	359,273	3,466,755	13,750,635	9,314,255	41,830,217	128,451,970
1900	185,783	5,504,310	147,528	8,183,390	6,181	3,157,625	365,742	3,365,310	17,125,190	10,193,970	46,845,739	193,032,280

Year.	Coke and Cinders.		Coal, etc., for Steam'rs (*b*)	Coal Products. (*c*)	Copper Sulphate.		Copper.			
							Unwrought, In Ingots, etc.		Mixed or Yellow Metal.	
1896....	687,640	$2,191,980	$10,096,302	$9,168,630	53,464	$4,303,315	23,698	$5,697,555	11,428	$2,576,510
1897....	993,980	3,372,525	10,623,050	8,340,420	60,326	5,113,800	21,252	5,381,155	11,192	2,640,740
1898....	782,053	2,755,580	11,444,431	7,624,740	52,573	4,224,085	27,102	7,154,225	10,452	2,542,915
1899....	881,172	3,743,745	12,422,429	7,712,965	40,822	4,261,185	32,449	11,994,300	7,038	2,186,940
1900....	(*d*)	(*d*)	11,940,353	9,060,870	43,601	5,067,970	18,300	6,993,065	8,940	2,946,515

Year.	Copper.—*Con.*		Glass, All Kinds	Iron.							
	Wrought or Manufactured. N. E. S. (*e*)			Pig and Puddled.		Bar (Except Railroad), Angle, Bolt and Rod.		Railroad, of All Sorts.		Iron and Steel Wire and Manufactures. (Except Telegraph Wire.)	
1896....	15,593	$4,220,155	$4,462,445	1,077,128	$12,669,415	180,973	$5,471,445	759,625	$17,802,050	57,008	$4,519,975
1897....	15,275	4,445,120	4,359,535	1,219,958	14,461,865	170,285	5,421,865	795,983	19,293,670	52,471	4,332,965
1898....	13,765	4,629,480	4,410,205	1,058,973	13,684,020	152,911	4,978,125	619,976	15,081,280	44,954	3,864,220
1899....	11,231	4,296,590	4,578,415	1,401,365	23,921,785	161,679	6,136,680	601,266	15,652,560	50,041	4,441,005
1900....	19,164	7,301,390	5,172,910	1,451,406	30,993,655	159,628	7,705,290	471,383	16,011,255	39,104	4,522,835

Year.	Iron.—*Continued.* Hoops, Sheets (Ungalvanized) and Boiler and Armor Plates.		Galvanized Sheets.		Black Plates for Tinning. (Iron and Steel.)		Tinned Plates.		Cast and Wrought, and Manufactures. N. E. S. (*e*)	
1896....	122,660	$4,226,140	248,348	$14,218,110	49,179	$2,389,995	271,234	$15,180,075	372,090	$23,598,685
1897....	120,868	4,483,370	231,319	12,810,420	59,663	2,844,645	276,260	15,186,395	382,179	24,436,375
1898....	102,638	3,916,335	230,219	12,653,350	59,299	2,706,435	255,797	13,768,540	361,927	23,630,065
1899....	111,773	4,661,900	242,167	15,607,050	86,936	4,189,790	260,735	15,838,415	363,855	25,160,490
1900....	86,382	4,696,840	251,208	18,942,885	66,810	3,524,335	278,338	19,891,880	344,901	29,362,285

Year.	Iron.—*Concluded.* Old.		Steel, Unwrought.		Manufactures of Steel and Iron.		Total of Iron and Steel.	
1896.....	129,463	$1,694,535	802,198	$12,587,775	37,299	$4,650,350	3,607,204	$119,008,500
1897.....	99,259	1,195,925	804,249	13,083,895	47,626	5,706,825	3,750,122	123,198,215
1898.....	86,602	1,201,050	290,182	13,203,560	35,857	4,513,470	3 299,326	113,200,460
1899.....	118,262	1,952,620	333,837	16,842,310	45,181	5,109,295	3,777,098	140,463,900
1900.....	96,567	1,876,400	313,330	18,425,090	42,939	5,135,170	3,602,083	160,085,785

Year.	Lead. Pig.		Lead. Sheet, Pipe and Other Manufactures.		Potassium Nitrate.		Mica and Talc.		Salt, Rock and Brine.		Slate.
1896..	18,976	$1,067,590	22,898	$1,549,245	29,994	$165,590	30	$33,125	671,510	$2,351,650	$954,220
1897..	20,749	1,254,985	20,162	1,437,585	23,372	117,995	39	55,100	680,477	2,332,620	1,043,110
1898..	18,964	1,231,360	19,720	1,499,410	20,859	134,310	89	69,065	608,882	2,300,075	988,905
1899..	21,083	1,512,850	19,840	1,667,135	25,608	131,725	70	62,400	638,213	2,237,080	934,605
1900..	17,764	1,536,320	18,812	1,912,480	25,659	128,295	71	46,350	556,704	2,289,150	739,000

Year.	Stone, All Kinds.		Tin, Unwrought.		Zinc. Ore.		Zinc. Crude.		Zinc. Manufactures.		Metals, Unclassified Wrought & Unwrought.
1896....	40,144	$779,280	6,299	$1,967,390	3,368	$42,575	8,605	$545,195	1,034	$126,456	$2,683,940
1897....	24,381	578,895	5,050	1,616,000	6,072	78,660	6,951	484,055	1,047	134,440	2,963,185
1898....	27,569	606,930	5,557	1,974,480	6,483	93,365	7,577	618,875	1,227	168,685	3,164,995
1899....	30,728	612,690	4,785	2,987,655	8,171	144,420	5,492	561,460	1,249	207,280	3,559,880
1900....	36,309	770,210	5,713	3,816,700	13,913	207,770	7,186	650,620	1,159	183,605	4,196,940

EXPORTS OF FOREIGN AND COLONIAL PRODUCE. (*a*) (IN METRIC TONS AND DOLLARS; £1 — $5.)

Year.	Chemical Products.	Copper, Unwrought, Partly Wrought, and Old.		Glass. Bottles, *Gross.*		Glass. All Other Kinds	Glass. Total.		Iron, Bar, Angle, Bolt, and Rod.		Steel, Unwrought.	
1896....	$1,003,585	9,809	$2,338,295	12,335	$24,895	3,324	$292,575	$317,470	16,882	$638,705	4,000	$167,345
1897 ...	1,295,400	10,307	2,526,150	11,666	26,670	4,320	376,305	402,975	21,842	962,905	4,244	194,980
1898....	1,509,195	13,454	3,578,710	12,694	29,875	3,961	353,905	383,780	26,891	1,125,450	2,619	154,480
1899....	1,085,185	24,515	9,160,530	13,768	29,915	3,172	257,180	287,095	19,058	879,680	3,289	149,165
1900....	1,178,710	19,163	7,201,390	18,638	52,685	2,150	159,150	211,835	11,116	547,065	2,837	139,870

Year.	Iron and Steel, N. E. S., Wrought and Manufactured. (*e*)		Petroleum. *Liters.*		Potassium Nitrate.		Quicksilver.		Tin, in Blocks, Ingots, Bars, or Slabs.	
1896.....	37,292	$3,712,450	11,709,283	$354,420	1,913	$152,765	1,198	$1,150,020	19,007	$5,669,945
1897.....	29,305	4,324,980	6,753,750	270,735	2,949	218,610	1,047	1,050,330	14,994	4,545,810
1898.....	29,509	5,658,860	6,479,451	217,200	2,775	203,030	1,157	1,199,500	15,885	5,310,350
1899.....	28,874	5,094,390	6,699,181	279,505	1,573	122,240	1,097	1,316,190	17,120	9,953,060
1900.....	....	4,348,005	9,077,474	354,495	1,581	128,295	880	1,188,705	20,069	13,101,260

(*a*) From *Accounts Relating to Trade and Navigation of the United Kingdom.* (*b*) Number of tons shipped for the use of steamers engaged in the foreign trade. This not being an export in the ordinary acceptation of the term, the value thereof is not given in the trade returns. (*c*) Including naphtha, paraffine, paraffine oil and petroleum. (*d*) Included in exports of coal and culm for this year. (*e*) N. E. S. signifies "not elsewhere specified."

UNITED STATES.

STATISTICS and full particulars of the mineral production of the United States will be found in the introduction and the articles on the different substances. We give below the mineral imports and exports for five years:

MINERAL IMPORTS OF THE UNITED STATES. (*a*)

Year.	Aluminum.							Ammonium Sulphate.			
	Crude.				Leaf.		Mfd.				
	Lb.	Kg.	Value.	Value per Kg.	Pkgs.	Value.	Value.	Lb.	Metric Tons.	Value.	Value per Met. Ton.
1897.....	1,822	854	$1,082	$1·26	4,260	$370	$3,279	19,351,119	8,778	$317,121	$36·13
1898.....	60	27	30	1·11	2,000	174	4,675	11,057,772	5,016	210,073	41·88
1899.....	53,622	24,323	9,425	0·39	693	112	5,308	17,121,988	7,766	406,573	52·35
1900.....	256,559	116,374	44,455	0·38	1,103	102	3,111	24,024,188	10,897	591,037	54·32
1901.....	564,808	251,657	104,168	0·41	*Nil.*	*Nil.*	5,580	31,711,085	14,384	726,085	50·62

Year.	Antimony.				Antimony Ore.			
	Lb.	Metric Tons.	Value.	Value per Metric Ton.	Lb.	Metric Tons.	Value.	Value per Metric Ton.
1897.....	1,146,696	520	$46,955	$90·30	5,502,132	2,496	$167,373	$67·06
1898.....	2,025,133	919	143,909	156·59	3,725,222	1,690	50,256	29·74
1899.....	3,160,697	1,434	240,988	168·09	3,982,133	1,806	47,841	26·49
1900.....	3,632,843	1,648	285,749	173·41	6,035,734	2,738	78,581	28·70
1901.....	3,674,923	1,667	255,346	153·17	1,731,956	786	24,256	30·86

Year.	Asbestos.			Asphaltum.			
	Crude. Value.	Manufactured. Value.	Total Value.	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.
1897.....	$264,220	$10,570	$274,790	127,325	129,362	$427,390	$3·30
1898.....	287,036	12,899	300,535	67,711	68,794	202,452	2·94
1899.....	303,119	8,949	312,068	100,168	101,771	319,089	3·14
1900.....	331,796	24,155	355,951	113,557	115,374	404,921	3·57
1901.....	667,087	24,741	691,828	132,079	134,192	516,515	3·85

Year.	Barium Sulphate.								Bauxite.			
	Manufactured.				Unmanufactured.							
	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Lb.	Metric Tons.	Value.	Value per Met. Ton.
1897....	1,300	1,321	$13,822	$10·46	502	510	$579	$1·14	5,924,639	2,695	$10,515	$3·90
1898....	687	698	8,678	12·43	1,022	1,038	2,678	2·58	2,690,240	1,220	4,238	3·47
1899....	2,111	2,145	22,919	10·69	1,739	1,767	5,488	3·11	14,931,840	6,773	23,768	3·51
1900....	2,454	2,493	24,160	9·69	2,568	2,609	8,301	3·18	19,389,440	8,795	32,967	3·75
1901....	2,454	2,493	27,002	10·85	3,150	3,200	12,380	3·87	40,021,120	18,153	66,107	3·64

Year.	Brass and Manufactures of. Value.	Chloride of Lime, or Bleach. Lb.	Metric Tons.	Value.	Value per Met. Ton.	Cement. Barrels. (b)	Metric Tons.	Value.	Value per Met. Ton.
1897.....	$85,341	109,176,451	49,522	$1,460,790	$29·50	2,090,894	879,857	$2,698,122	$7·09
1898.....	24,611	108,462,828	49,196	1,229,978	25·00	2,013,819	365,385	2,624,228	7·18
1899.....	58,916	123,583,061	56,056	1,203,864	21·47	2,108,213	382,512	2,858,256	7·47
1900.....	20,113	132,520,478	60,111	1,524,205	25·36	2,395,694	435,097	3,390,453	7·69
1901.....	35,976	117,510,359	53,302	1,673,190	31·49	939,335	170,481	1,305,692	7·66

Year.	Chrome Ore. Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Chromic Acid. Lb.	Kg.	Value.	Value per Kg.	Clays or Earths, Including Kaolin. Long Tons.	Metric Tons	Value.	Value per Met. Ton.
1897..	11,566	11,751	$186,313	$15·85	71,220	32,305	$5,477	$0·17	102,391	104,029	$696,985	$6·70
1898..	16,304	16,565	272,234	16·43	5,329	2,417	1,758	0·73	113,280	115,092	779,491	6·77
1899..	15,793	16,046	284,825	17·75	33,134	15,029	6,360	0·42	122,085	123,988	807,792	6·52
1900..	17,542	17,823	305,001	17·11	35,452	16,081	7,232	0·45	146,524	148,868	966,579	6·49
1901..	20,112	20,434	363,108	17·77	53,462	24,252	10,861	0·45	151,013	153,589	1,176,633	6·41

Year.	Coal. Anthracite. Long Tons.	Metric Tons.	Value.	Value Per Met. Ton.	Bituminous. Long Tons.	Metric Tons.	Value.	Value Per Met. Ton.	Total. Metric Tons.	Value.	Value Per Met. Ton.
1897	3,281	3,333	$8,720	$2·62	1,276,963	1,297,394	$3,423,434	$2·64	1,300,728	$3,432,154	$2·64
1898	3,149	3,199	8,000	2·69	1,270,557	1,290,886	3,569,572	2·77	1,294,085	3,578,181	2·77
1899	61	62	245	3·95	1,400,461	1,422,868	3,882,430	2·73	1,422,930	3,882,675	2·73
1900	118	120	549	4·58	1,909,258	1,939,806	5,019,553	2·59	1,939,927	5,020,102	2·59
1901	286	291	1,844	6·34	1,919,902	1,950,681	5,291,429	2·71	1,950,972	5,293,273	2·71

Year.	Coke. Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Cobalt Oxide. Lb.	Kg.	Value.	Value per Kg.	Copper, Ore and Regulus. Lb.	Metric Tons.	Value.	Value per Met. Ton.
1897	35,793	35,756	$98,558	$2·76	$24,771	11,236	$34,773	$3·09	11,587,520	5,256	$816,590	$155·36
1898	41,185	41,844	142,334	3·40	33,731	15,300	49,245	3·22	6,861,120	3,112	654,355	210·26
1899	27,855	28,301	142,504	5·04	46,791	21,224	68,847	3·24	70,806,880	32,145	2,243,583	65·56
1900	103,175	104,826	371,341	3·54	54,073	24,527	88,651	3·61	121,696,960	55,201	5,195,010	90·76
1901	72,729	73,893	266,078	3·61	71,969	32,645	134,208	4·11	215,133,686	97,584	14,692,645	150·58

Year.	Copper, Ingots, Old, etc. Lb.	Metric Tons.	Value.	Value per Met. Ton.	Copper, Manufactures. Value.	Copper, Total Value.	Cryolite. Long Tons.	Metric Tons.	Value.	Value per Met. Ton.
1897....	16,578,420	7,520	$1,454,016	$193·35	$58,897	2,929,503	10,115	10,277	$135,114	$13·24
1898....	54,166,467	24,570	4,120,680	167·71	39,467	4,814,502	6,201	6,300	88,501	14·05
1899....	71,922,340	32,624	10,139,390	310·80	42,000	12,424,978	5,879	5,973	78,676	13·17
1900....	68,796,808	31,206	10,557,870	338·33	23,390	15,776,370	5,437	5,524	72,763	13·17
1901....	73,826,406	33,488	11,812,216	352·73	24,775	26,529,696	5,383	5,469	70,896	12·96

Year.	Earthen, Stone, and China Ware Value.	Emery Grains. Lb.	Metric Tons.	Value.	Value per Met. Ton	Emery Rock. Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Emery Manufactures. Value.	Emery. Total Value.
1897....	$8,409,678	520,095	238	$20,022	$84·84	5,209	5,292	$107,649	$20·36	$2,211	$129,882
1898....	7,273,471	577,655	262	23,330	89·01	5,547	5,636	106,369	18·86	3,810	133,399
1899....	8,101,093	728,299	330	29,124	88·17	7,435	7,554	116,493	15·42	11,514	157,131
1900....	9,143,536	661,182	300	26,520	88·39	11,392	11,574	202,980	17·54	10,006	239,506
1901....	9,816,074	1,116,729	506	43,307	85·57	12,441	12,640	240,856	19·05	10,927	294,990

Year.	Fertilizers.								All Other. Value.	Gold and Silver in Coin and Bullion.	
	Guano.				Phosphates, Crude.						
	Long Tons.	Metric Tons	Value.	Value per Met. Ton.	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.		Gold.	Silver.
1897....	4,931	5,019	$55,709	$11·12	8,019	8,147	$65,137	$8·00	$1,295,804	$29,081,760	$12,146,750
1898....	5,259	5,348	56,933	10·66	66,129	67,187	303,635	4·52	1,045,113	153,146,159	9,572,310
1899....	2,700	2,743	26,787	9·76	115,913	117,768	523,258	4·44	986,127	40,070,599	8,940,842
1900....	6,620	6,726	67,413	9·91	137,086	139,272	791,189	5·68	1,400,396	45,703,256	14,695,965
1901....	6,252	6,352	74,670	11·75	174,462	177,253	868,993	4·96	1,506,965	33,237,629	12,957,987

Year.	Gold and Silver in Ores.		Iron Ore.				Pig Iron.			
	Gold.	Silver.	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.
1897.....	$4,941,052	$20,995,552	489,970	497,809	$678,912	$1·39	19,212	19,519	$484,655	$24·83
1898.....	5,017,793	19,559,070	187,098	190,086	253,243	1·33	25,152	25,554	704,431	27·56
1899.....	11,364,365	21,903,087	674,082	684,867	1,082,847	1·58	40,393	41,039	1,339,405	32·64
1900.....	21,045,828	25,404,574	879,831	893,908	1,303,196	1·48	52,565	53,406	1,907,361	35·71
1901.....	21,524,251	18,188,795	966,950	982,421	1,659,273	1·69	62,930	63,937	1,792,014	28·08

Year.	Scrap Iron and Steel.				Bar Iron, Rolled and Hammered.				Bars, Railway, of Iron or Steel.			
	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Lb.	Metric Tons.	Value.	Value per Met. Ton.	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.
1897	$1,549	1,573	$12,433	$7·26	31,349,707	14,220	$614,318	$43·20	415	422	$15,989	$37·77
1898	1,783	1,812	33,330	18·39	42,827,276	19,426	844,365	43·47	300	203	5,181	25·52
1899	10,925	11,100	168,045	15 14	44,333,056	20,109	942,347	46·86	2,134	2,168	70,751	32·65
1900	34,431	34,982	663,231	18·96	44,098,825	19,094	1,058,761	55·45	1,448	1,471	56,129	38·15
1901	20,130	20,452	339,827	16·56	46,601,251	20,000	1,102,868	55·14	1,905	1,935	67,052	35·17

Year.	Hoop, Band, or Scroll.				Ingots, Blooms, Slabs, Billets, etc.				Sheet, Plate, and Taggers Iron or Steel.			
	Lb.	Met. Tons.	Value.	Value per Met. Ton.	Lb.	Met. Tons.	Value.	Value per Met. Ton.	Lb.	Metric Tons.	Value.	Value per Met. Ton.
1897	61,916	28	$2,873	$102·61	38,600,934	17,509	$1,523,410	$87·00	5,854,990	2,656	$170,385	$64·15
1898	7,527	3	224	74·66	23,808,663	10,827	1,008,360	93·13	5,085,287	2,307	181,021	78·47
1899	1,485,720	674	33,392	49·54	28,225,647	12,803	1,287,725	100·58	15,777,163	7,156	464,297	64·88
1900	369,165	167	12,409	74·08	28,468,816	12,913	1,332,896	103·19	11,521,161	5,226	426,541	81·62
1901	6,660,909	3,021	116,841	38·67	18,259,393	8,282	1,330,985	160·69	12,601,896	5,716	443,880	77·85

Year.	Ties for Baling Cotton.				Tin Plates, Terne Plates, and Taggers Tin.			
	Lb.	Metric Tons.	Value.	Value per Metric Ton.	Lb.	Metric Tons.	Value.	Value per Metric Ton.
1897.....	235,154	107	$3,686	$34·45	187,825,880	85,198	$4,366,828	$51·25
1898.....	*Nil.*	.....	.....	.....	149,576,525	67,847	3,311,658	48·81
1899.....	*Nil.*	.....	.....	.....	131,970,441	59,861	3,738,567	62·45
1900.....	*Nil.*	.....	.....	.....	135,264,791	61,356	4,617,813	75·26
1901.....	*Nil.*	.....	.....	.....	173,364,176	78,638	5,294,789	.....

Year.	Wire Rods.				Wire, and Articles made from.				Manufactures. Value.
	Lb.	Metric Tons.	Value.	Value per Met. Ton.	Lb.	Metric Tons.	Value.	Value per Met. Ton	
1897.....	36,768,538	16,679	$772,950	$46·34	5,720,822	2,596	$344,855	$132·84	$5,523,678
1898.....	35,807,368	16,242	767,909	47·28	4,516,761	2,049	318,553	155·46	5,209,542
1899.....	40,289,103	18,252	873,396	47·85	5,293,069	2,401	400,952	166·99	6,481,702
1900.....	47,245,140	21,430	1,212,594	56·58	4,138,991	1,877	409,087	217·90	8,747,099
1901.....	37,640,504	17,073	964,744	56·50	9,247,231	4,192	585,354	139·64	8,356,646

Year.	Total Value of Iron Imports. (e)	Lead, Pig, Bars, Scrap, and in Ore.				Lead, Sheet, Pipe, Shot, etc.	
		Lb.	Metric Tons.	Value.	Value per Metric Ton.	Lb.	Metric Tons.
1897.....	$13,835,950	185,318,412	84,060	$2,480,471	$29·51	95,891	43
1898.....	12,474,572	179,291,290	81,326	2,535,362	31·18	242,759	110
1899.....	15,800,579	192,877,074	87,488	2,816,788	32·20	110,372	50
1900.....	20,443,911	226,703,449	102,780	3,957,605	38.13	27,945	13
1901.....	20,394,995	224,942,329	102,332	4,843,061	47·52	56,785	26

Year.	Lead, Sheet, Pipe, Shot, etc.—*Continued.*		Lead, Other Manufactures. Value.	Lead, Total Value.	Manganese Ore.			
	Value.	Value per Met. Ton.			Long Tons.	Metric Tons.	Value.	Value per Met. Ton.
1897.....	$4,042	$94·00	$814	$2,485,327	39,574	40,207	$340,945	$8·48
1898.....	9,389	85·35	*Nil.*	2,544,751	114,885	116,723	831,967	7·13
1899.....	4,402	74·61	12,983	2,834,168	188,349	191,363	1,534,538	8·28
1900.....	1,398	109·68	5,854	3,964,949	256,252	260,352	2,042 361	7·84
1901.....	2,778	106,65	4,654	4,850,508	165,720	168,372	1,486,578	8·83

Year.	Marble and Stone, and M'f'res of.			Metals, Metal Compositions, and Manufactures of, N.E.S.			Mica, Mineral Substances, and Nickel.		
	Marble and Manufactures of.	Stone and Manufactures of.	Total.	Bronze Manufactures.	All Other.	Total.	Mica.	Mineral Substances N. E. S.	Nickel.
	Value.	Value. (d)	Value.	Value.	Value.	Value.	Value.	Value.	Value.
1897	$860,659	$263,381	$1,124,040	$526,741	$3,543,827	$4,070,568	$159,616	$78,373	$53,013
1898	726,343	229,909	956,252	508,814	3,479,221	3,988,035	150,082	19,160	(f)
1899	726,070	200,192	926,262	710,086	4,008,942	4,719,028	275,984	78,458	(f)
1900	945,705	256,624	1,202,329	791,806	5,420,483	6,211,789	319,560	71,377	(f)
1901	1,226,524	237,191	1,463,715	945,702	5,162,392	6,108,094	335,054	109,043	1,687,166

Year.	Oil, Mineral.				Paints, Mineral. Zinc Oxide in Oil.				Paints and Colors.	Platinum, Man'f'ur'd.
	Gallons.	Liters.	Value.	Value per Liter.	Lb.	Metric Tons.	Value.	Value pr. Met. Ton.	Value.	Value.
1897.....	949,178	3,592,638	$77,789	$0·021	502,357	228	$19,608	$86·00	$1,319,894	$121
1898.....	2,024,090	7,661,808	146,713	·019	27,050	12	2,279	189·92	1,142,670	271
1899.....	1,107,077	4,190,630	108,047	·025	41,699	19	4,154	219·79	1,412,877	876
1900.....	3,089,094	11,503,913	274,766	·024	38,706	18	3,098	176·02	1,491,902	827
1901.....	2,294,684	8,686,389	151,913	·018	128,198	58	8,963	154·88	1,524,125	2,513

Year.	Platinum, Unmanufactured.			Plat'm Vases, Retorts	Potash, Chlorate of.				Potash, Chromate & Bichromate.			
	Kg.	Value.	Val. per Kg.	Value.	Lb.	Metric Tons.	Value.	Val. per Metric Ton.	Lb.	Met. Tons.	Value.	Value per Met. Ton.
1897	2,584·14	$960,299	$371·61	$43,800	6,508,359	2,950	$461,620	$156·38	1,329,478	603	$108,497	$179·93
1898	3,142·07	1,178,142	374·96	52,012	4,805,332	2,180	288,965	132·55	1,160,710	526	66,134	163·75
1899	3,041·32	1,482,157	487·34	54,877	1,534,657	696	102,189	146·82	1,130,965	513	73,510	143·29
1900	3,450·06	1,728,777	501·81	35,897	1,243,612	564	68,772	121·94	111,761	51	7,758	153·02
1901	2,796·90	1,673,713	598·42	21,969	811,127	368	61,348	166·71	430,996	195	29,234	149·86

Year.	Potash, Muriate of.				Potash, Nitrate of.				Potash, all other.	
	Lb.	Metric Tons.	Value.	Val. per Metric Ton.	Lb.	Metric Tons.	Value.	Value per Met. Ton.	Lb.	Metric Tons.
1897.....	108,839,049	49,369	1,683,472	$34·10	16,276,352	7,383	$306,696	$41·54	30,311,863	13,749
1898.....	103,368,701	46,888	1,620,720	34·57	11,461,823	5,199	281,504	54·15	37,736,761	17,117
1899..	117,449,708	53,275	1,819,448	34·15	18,961,270	8,601	377,371	43·88	46,453,415	21,071
1900.....	130,175,481	59,047	1,976,604	33·48	10,545,392	4,783	276,664	57·84	54,904,088	24,904
1901.....	144,189,337	65,404	2,316,577	35·39	9,600,393	4,355	251,783	57·81	72,489,913	32,881

Year.	Potash, all other. *Continued.*		Precious Stones.		Pyrites.				
			Rough & Uncut.	Cut.					
	Value.	Value per Metric Ton.	Value.	Value.	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Average Sulphur Contents.
1897	$667,209	$48·53	1,425,614	$5,090,125	259,546	263,699	$874,419	$3·32	25%
1898	827,556	48·35	2,550,076	7,388,086	171,879	174,629	544,165	3·12	Over 25%
1899	1,014,962	48·16	4,955,587	11,653,917	310,008	314,968	1,074,855	3·41	Over 25%
1900	1,407,308	56·51	3,751,219	9,612,127	332,517	337,837	1,095,598	3·24	Over 25%
1901	1,636,856	49·78	6,637,860	17,162,421	398,969	405,353	1,407,244	3·47	Over 25%

Year.	Quicksilver.	Salt.				Soda, Nitrate of.			
	Value.	Lb.	Metric Tons.	Value.	Value per Met. Ton.	Long Tons.	Metric Tons.	Value.	Value Per Met. Ton.
1897	$20,147	461,813,843	209,479	$611,166	$2·44	94,965	96,484	$2,810,187	$29·12
1898	51	374,310,225	169,786	587,348	3·46	147,494	149,854	2,298,240	15·34
1899	83	386,878,938	175,360	587,103	3·35	145,492	149,836	3,486,318	23·42
1900	1,051	415,865,592	188,636	633,192	3·36	182,108	185,022	4,985,590	26·78
1901	.....	389,924,426	176,871	670,648	3·79	208,679	212,018	5,999,098	28·29

Year.	Soda, Bicarbonate.				Soda, Caustic.			
	Lb.	Metric Tons.	Value.	Value per Metric Ton.	Lb.	Metric Tons.	Value.	Value per Metric Ton.
1897	995,669	438	$13,993	$31·92	57,742,392	26,192	$986,318	$37·73
1898	280,988	127	5,794	45·62	24,981,678	11,332	354,270	31·26
1899	162,398	74	5,219	70·61	13,363,529	6,062	186,008	30·68
1900	133,137	60	4,509	74·05	8,403,749	3,812	150,530	39·49
1901	154,653	70	4,727	67·53	3,812,847	1,725	94,308	54·65

Year.	Soda Ash and Sal Soda.				All other Soda Salts.			
	Lb.	Metric Tons.	Value.	Value per Metric Ton.	Lb.	Metric Tons.	Value.	Value per Metric Ton
1897	154,656,060	70,152	$1,122,867	$16·00	7,927,145	3,596	$100,989	$28·08
1898	73,064,707	33,142	447,119	13·49	23,354,802	10,594	256,962	24·26
1899	56,053,837	25,426	425,255	16·72	26,598,238	12,062	360,721	29·90
1900	73,815,425	33,482	613,379	18·32	20,484,988	9,292	259,802	26·02
1901	31,415,788	14,786	276,961	14·71	14,491,559	6,573	189,543	28·08

Year.	Sulphur, Crude.				Sulphur, Flowers.				Sulphur, Refined.			
	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.
1897	138,846	141,067	$2,443,490	$17·31	319	324	$7,950	$24·54	148	150	$3,387	$22·58
1898	159,790	162,347	3,081,974	18·98	507	515	14,548	28·25	163	166	4,391	26·45
1899	140,841	143,094	2,494,887	17·43	336	341	9,917	29·08	184	187	4,519	24·17
1900	166,457	169,120	2,918,610	17·26	628	638	17,437	27·33	243	247	6,279	25·43
1901	174,194	176,981	3,261,397	18·43	748	761	20,201	26·54	268	272	6,308	23·20

Year.	Talc.				Tin.			
	Lb.	Metric Tons.	Value.	Value per Metric Ton.	Lb.	Metric Tons.	Value.	Value per Met. Ton.
1897	1,597,849	725	$8,423	$11·61	55,172,571	25,026	$7,415,933	$296·33
1898	899,645	404	5,526	13·68	62,748,399	28,462	8,770,221	308·49
1899	508,553	231	3,534	15·32	71,248,407	32,318	16,746,105	518·17
1900	158,497	72	1,070	14·86	69,969,502	31,747	19,458,586	612·98
1901	4,771,781	2,164	27,015	12·49	74,560,487	33,820	19,024,761	562·58

Year.	Zinc. Block, Pig, and Old. Lb.	Metric Tons.	Value.	Value per Met. Ton.	Manufactures of. Net Value.	Total Value.
1897.....	2,557,341	1,160	$95,883	$82·66	$19,431	$115,314
1898.....	2,742,357	1,244	109,624	88·12	13,448	123,072
1899.....	2,985,463	1,354	151,956	112·23	14,800	166,756
1900.....	2,013,196	913	97,772	107·05	36,836	134,598
1901.....	775,881	352	30,990	87·84	42,643	73,563

(a) From *Summary of Commerce and Finance of the United States.* (b) Custom-house returns for these years are given in pounds, which are reduced to barrels of 400 lb. for convenience of comparison. (d) Including slate. (e) Not including ore. (f) Not reported.

MINERAL EXPORTS OF DOMESTIC PRODUCTION OF THE UNITED STATES. (a)

Year.	Aluminum and Manufactures of.	Asbestos.	Brass & Manufactures of.	Cement.				Chemicals, Drugs and Medicines.	Coal. Anthracite.	
		Value.	Value.	Bbls.	Metric Tons(m)	Value.	Value per Met. Ton.	Value.	Long Tons.	Metric Tons.
1897....	(n)	73,736	$1,346,802	53,466	9,701	$93,684	$9·66	$9,633,381	1,298,788	1,319,548
1898....	$239,997	54,660	1,237,027	36,732	6,665	73,838	11·08	9,732,734	1,350,948	1,372,563
1899....	291,515	77,409	1,607,072	81,090	14,713	166,073	11·29	11,949,884	1,707,796	1,735,121
1900....	281,821	124,971	2,068,072	100,400	18,216	225,306	12·37	13,771,682	1,654,610	1,681,064
1901....	183,579	113,316	2,078,178	373,934	67,393	679,296	10·79	14,254,596	1,998,307	2,035,200

Year.	Coal.—*Continued.* Anthracite.—*Con.* Value.	Val. per Met. Ton.	Bituminous. Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Total Long Tons.	Total Metric Tons.	Total Value.	Copper Ore. (c) Lb.	Metric Tons.
1897	$5,836,730	$4·42	2,399,263	2,437,651	$5,326,761	2·19	3,698,031	3,757,199	$11,163,491	20,303,360	9,209
1898	5,712,985	4·15	3,152,457	3,202,896	6,699,948	2·09	4,503,405	4,575,459	12,412,233	20,923,320	9,492
1899	7,140,100	4·12	4,044,354	4,109,064	8,573,276	2·09	5,752,150	5,844,184	15,713,376	8,393,260	3,807
1900	7,092,489	4·22	6,262,909	6,363,681	14,431,590	2·27	7,917,519	8,043,996	21,524,079	22,415,680	10,168
1901	8,987,147	4,41	5,390,086	5,476,327	13,085,763	2·49	7,383,393	7,501,527	22,072,910	43,983,120	19,927

Year.	Copper Ore.—*Con.* (c) Value.	Val. per Metric Ton.	Copper, Pig, Sheet, and Old. Lb.	Metric Tons.	Value.	Val. per Met. Ton.	Copper. Manufactures. Value.	Copper. Total Value.	Earthen, and China Ware. Value.
1897.....	$1,199,029	130·20	277,255,742	125,763	$30,627,945	$243·54	$958,379	$32,785,353	$207,608
1898.....	755,443	79·59	291,955,905	132,480	33,598,869	253·71	1,190,239	35,545,251	251,831
1899.....	442,868	115·32	246,826,331	111,960	41,190,287	367·90	1,852,499	43,485,654	511,732
1900.....	1,332,829	131·08	337,973,751	153,304	55,285,047	360·51	2,257,563	58,875,439	558,794
1901.....	2,536,549	127·80	194,249,828	88,111	31,692,563	359·70	1,842,336	36,071,448	596,820

Year.	Fertilizers. Phosphates, Crude. Long Tons.	Metric Tons.	Value.	Value per Met. Tons	All Other. Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Glassware. Value.	Gold and Silver in Coin and Bullion. (e) Gold.	Silver.
1897....	551,046	559,863	$5,136,546	$9·17	(o)	.....	.....	.....	$1,234,559	$24,174,182	$58,352,274
1898....	570,948	580,083	4,672,463	8·05	16,714	16,981	$442,977	$26·09	1,269,919	16,113,268	53,673,605
1899....	867,790	881,675	6,770,102	7·68	49,082	49,867	1,081,882	20·69	1,716,643	45,317,461	53,492,242
1900....	619,925	629,915	5,217,560	8·25	25,976	26,392	537,908	20·38	2,042,633	54,064,697	65,705,909
1901....	729,633	741,317	5,841,495	7·88	14,059	141,284	330,714	23·15	2,087,043	56,717,300	55,527,518

Year.	Gold and Silver in Ores. (f) Gold.	Silver.	Iron Ore. Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Iron, Pig. Long Tons.	Metric Tons.	Value.	Value per Met. Ton.
1897.....	$102,219	$309,018	7,583	7,704	$24,612	$3·19	262,686	266,889	$3,269,010	$12·25
1898.....	81,696	123,499	31,579	32,084	67,548	2·11	253,057	257,106	2,703,551	10·51
1899.....	61,950	39,495	40,665	41,316	76,287	1·85	228,678	232,337	3,293,641	14·13
1900.....	99,926	515,755	51,460	52,283	154,756	2·96	286,697	291,404	4,654,589	15·97
1901.....	828,143	111,383	64,708	65,748	163,485	2·49	81,178	82,477	1,359,499	15·27

Year.	Iron, Bar.				Iron, Band, Hoop and Scroll.				Billets, Ingots, and Blooms.			
	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.
1897	4,493	4,566	$150,897	$33·05	1,424	1,446	$44,754	30·95	6,356	6,458	$108,333	$16·78
1898	7,074	7,188	241,499	33·60	1,593	1,619	58,781	36·28	28,600	29,058	544,771	18·75
1899	10,898	11,073	413,694	37·36	2,869	2,915	117,002	40·14	25,497	25,895	532,941	20·59
1900	13,298	13,512	558,576	41·38	2,976	3,024	137,437	45·45	107,385	109,103	2,915,371	26·72
1901	17,708	17,998	674,671	37·50	1,561	1,586	74,056	46·69	28,614	29,072	708,887	24·38

Year.	Iron, Nails and Spikes, Cut.				Iron Nails & Spikes; Wire, Wrought, Horseshoe and all other, inc. Tacks.				Plates and Sheets of Iron.			
	Lb.	Metric Tons.	Value.	Val. per Metric Ton.	Lb.	Metric Tons.	Value.	Val. per Met. Ton.	Lb.	Metric Tons.	Value.	Val. per Metric Ton.
1897	33,773,216	15,319	$670,709	$43·78	20,070,024	9,104	550,654	$60·49	9,061,447	4,110	$175,799	$42·77
1898	35,247,266	15,988	641,779	40·20	35,409,789	16,062	839,299	52·25	10,008,903	4,538	204,170	44·99
1899	22,342,543	10,135	482,882	47·64	79,727,846	36,164	1,957,773	54·14	13,880,092	6,296	356,791	56·67
1900	25,005,308	11,342	626,497	55·24	65,444,387	29,681	1,816,813	61·21	20,902,367	9,481	600,600	63·34
1901	20,837,973	9,452	450,331	48·70	46,298,262	21,001	1,152,368	54·87	15,466,168	7,015	452,695	64·53

Year.	Plates and Sheets of Steel.				Rails or Bars of Iron.				Rails or Bars of Steel.			
	Lb.	Metric Tons.	Value.	Val. per Metric Ton.	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.
1897	11,364,891	5,155	$173,567	$33·66	5,413	5,499	$95,520	$17·37	142,808	145,093	2,949,201	$20·33
1898	60,647,662	27,510	787,245	28·62	8,311	8,444	101,109	11·97	298,592	298,289	5,838,464	19·57
1899	113,422,814	51,448	1,690,490	32·86	6,442	6,545	96,135	14·69	271,272	275,612	6,122,382	22·21
1900	101,995,225	46,264	1,636,478	35·41	5,374	5,460	119,206	21·83	356,245	361,945	10,895,416	30·10
1901	53,566,154	24,303	959,471	39·48	901	915	32,357	35·36	318,055	323,044	8,628,781	26.71

Year.	Structural Iron and Steel.				Wire.				Wire Rods. (Steel.)			
	Lon Tons	Metric Tons.	Value.	Val. per Met. Ton	Lb.	Met. Tons.	Value.	Value per Met. Ton.	Lb.	Metric Tons.	Value.	Val. per Met. Ton
1897	15,072	15,313	$604,339	$39·47	118,887,872	53,927	$2,353,829	$43·65	23,484,969	10,653	$240,737	$22·60
1898	84 039	34,588	1,255,451	36·30	167,252,882	75,865	3,036,818	40·03	41,462,596	18,807	390,144	20·74
1899	54,244	55,112	2,059,289	37·37	260,549,627	118,184	5,526,936	46·83	38,062,438	17,265	594,466	30·28
1900	67,714	68,797	3,570,769	51·90	174,751,042	79,267	4,604,047	58·08	23,860,018	10,823	505,589	46·62
1901	54,005	54,869	3,031,861	55·26	197,651,789	89,654	4,805,608	53·71	18,287,901	8,295	271,552	32·91

Year.	Lead & Manufactures.	Marble, Stone, & Manufactures of.	Mica.	Nickel. (g)	Petroleum (1 — 1,000 in Quantities and total Values.)							
					Crude.				Naphtha.			
	Value.	Value. (h)	Value.	Value.	Gallons.	Liters.	Value.	Value per Liter.	Gallons.	Liters.	Value.	Value per Liter.
1897	$433,319	$1,682,044	*Nil.*	$997,391	121,864	461,255	$5,044	$0·011	13,704	51,869	$1,030	$0·020
1898	215,239	1,842,220	$6,272	1,359,609	120,436	455,888	5,016	·011	17,258	65,326	1,071	·016
1899	273,919	1,900,763	4,655	1,151,923	117,690	445,495	5,958	·013	18,210	68,930	1,597	·023
1900	459,574	1,556,961	165	1,382,727	138,161	523,000	7,341	·014	18,570	70,295	1,681	·024
1901	624,534	1,785,515	3,584	1,521,291	127,008	480,781	6,038	013	21.685	82,087	1,742	·021

Year.	Petroleum —*Continued.*											
	Illuminating.				Lubricating.				Residue, etc.			
	Gallons	Liters.	Value.	Value per Liter.	Gallons.	Liters.	Value.	Value per Liter.	Gallons (j)	Liters.	Value.	Value per Liter.
1897	804,446	3,045,189	$46,876	$0·015	52,659	199,332	$6,782	$0·034	12,247	46,355	$335	$0·007
1898	764,893	2,894,191	38,895	·013	65,586	248,038	7,626	·031	30,436	115,209	615	·007
1899	733,392	2,776,134	49,172	·018	71,116	269,195	8,658	·032	21,609	81,798	658	·008
1900	730,163	3,104,593	54,698	·018	71,211	269,540	9,333	·037	19,750	74,760	845	·011
1901	827,222	3,131,399	53,491	·017	75,291	285,010	10,260	·036	27,596	104,463	1,255	·012

Year.	Petroleum.—*Concluded.* Paraffine. Lb.	Metric Tons.	Value.	Value per Met. Ton.	Quicksilver. Lb.	Metric Tons.	Value.	Value per Met. Ton.	Tin Manufactures. Value.
1897	136,069	61·7	$5,284	$85·61	1,007,770	457	$394,549	$863·35	$384,090
1898	166,817	75·4	6,263	84·34	981,497	445	440,587	990·08	281,794
1899	181,861	82·5	7,650	92·74	1,264,372	573	609,586	1,063·92	401,217
1900	157,108	71·2	8,186	114·86	778,191	353	425,812	1,206·61	467,354
1901	151,695	68·8	7,960	115·70	858,298	389	475,609	1,222·66	495,425

Year.	Zinc Ore. Lb.	Metric Tons.	Value.	Value per Met. Ton.	Zinc Oxide. Lb.	Metric Tons.	Value.	Value Per Metric Ton.
1897	18,502,400	8,398	$211,350	$25·18	3,718,507	1,687	$104,140	$61·74
1898	23,564,800	10,689	299,670	28·05	7,849,059	3,560	252,194	70·83
1899	56,441,280	25,600	725,944	28·36	10,685,226	4,847	366,508	75·64
1900	84,123,200	38,158	1,133,663	29·71	11,391,566	5,167	496,380	96·06
1901	88,312,000	40,058	1,167,684	29·15	9,122,283	4,138	393,259	95·03

Year.	Zinc; Pigs, Bars, Plates and Sheets. Lb.	Metric Tons.	Value.	Value per Met. Ton.	All Other Manufactures. Value.	Total Value.
1897	28,490,662	12,923	$1,356,538	$104·97	$71,021	$1,743,049
1898	20,998,413	9,525	1,083,959	108·55	188,165	1,794,188
1899	13,509,316	6,128	742,521	121·17	143,232	1,978,295
1900	44,802,577	20,322	2,217,693	109·13	99,296	3,947,094
1901	6,770,221	3,071	288,906	94·08	82,046	1,981,895

MINERAL EXPORTS OF FOREIGN PRODUCE FROM THE UNITED STATES. (*a*)

Year.	Antimony. Lb.	Metric Tons.	Value.	Value Per Metric Ton.	Antimony Ore. Lb.	Metric Tons.	Value.	Value Per Metric Ton.
1897	4,089	1·9	$987	$151·55	37,395	17·0	$2,348	$138·12
1898	25,275	11·4	1,729	151·67	34,321	15·6	784	50·26
1899	16,815	7·6	1,275	167·76	*Nil.*	.....	.....	.....
1900	23,520	10·7	2,352	219·81	*Nil.*	.....	.....	.....
1901	*Nil.*	*Nil.*	*Nil.*	*Nil.*	49,655	22·1	1,536	69·50

Year.	Asphaltum or Bitumen (Crude.) Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Brass and Manufactures of. Value.	Cement. Lb.	Metric Tons.	Value.	Value per Met. Ton
1897	40	41	$1,042	$25·41	$3,210	2,488,350	1,129	$9,705	$8·60
1898	1,514	1,538	28,666	18·64	1,080	6,574,658	2,982	24,283	8·14
1899	1,194	1,213	24,486	20·19	766	11,672,694	5,295	47,384	8·95
1900	629	639	10,044	15·73	2,155	15,815,851	7,174	63,880	8·90
1901	2,909	2,944	18,078	8·06	813	17,476,590	7,927	72,761	9,18

Year.	Chemicals. Salts of Potash. (*b*) Lb.	Kg.	Value.	Value per Kg.	Chloride of Lime. Lb.	Kg.	Value.	Value per Kg.	Nitrate of Soda. Lb.	Kg.	Value.	Value per Kg.
1897	124,277	56,372	$4,763	$0·08	40,916	18,559	$718	$0·04	2,022,720	917,506	$33,979	$0·04
1898	183,804	83,466	5,444	·07	28,605	12,975	881	·08	1,646,400	746,802	24,695	·03
1899	402,330	182,450	12,594	·07	*Nil.*	.....	.....	.....	5,510,400	2,499,501	78,877	·03
1900	808,701	366,824	43,594	·12	148,116	67,185	1,987	·03	6,919,360	3,138,601	112,550	·04
1901	633,100	287,182	43,446	·15	18,916	6,312	312	·05	5,559,680	2,518,543	101,489	·04

Year.	Chemicals—*Continued.*											
	Caustic Soda.				Sal Soda and Soda Ash.				All Other Salts of Soda.			
	Lb.	Kg.	Value.	Value per Kg.	Lb.	Kg.	Value.	Value per Kg.	Lb.	Kg	Value.	Value per Kg.
1897	1,824,565	827,623	$34,332	$0·04	2,246,161	1,018,868	$9,128	$0·01	20,797	9,433	$362	$0·03
1898	1,287,257	561,216	22,202	·04	4,247,945	1,926,855	14,255	·01	120,542	54,677	1,400	·03
1899	1,032,831	468,489	18,330	·04	1,173,781	532,424	4,198	01	93,590	42,420	2,085	·05
1900	1,139,954	517,080	24,228	·05	78,017	35,393	1,126	·03	270,307	122,610	2,788	·02
1901	1,001,940	452,482	21,511	·05	369,521	167,614	5,184	·03	183,400	60,510	3,398	·05

Year.	Clays or Earths of All Kinds, including China Clay.				Coal, Bituminous.				Copper.			
									Ore and Regulus.			
	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Long Tons.	Metric Tons.	Value	Value per Met. Ton.	Lb.	Metric Tons.	Value.	Val. per Met.Ton.
1897	16	16	$63	$3·98	5,297	5,382	$6,337	$1·18	1,328,320	603	$85,170	$141·24
1898	91	92	657	7·11	2,890	2,936	2,675	0·91	7,632,720	3,458	547,960	158·46
1899	152	154	1,304	8·44	6,806	6,915	9,598	1·39	3,841,600	1,743	265,336	152·22
1900	78	79	572	7·22	6,740	6,848	19,740	2·88	2,159,360	979	170,191	173·75
1901	80	81	825	10·18	3,796	4,403	10,627	2·41	22,155,840	10,050	1406,646	139·95

Year.	Copper.—*Continued.*					Earthen, Stone, and China-ware. Value.	Fertilizers.			
	Pigs, Bars, Ingots, Old, and Other Unmanufactured.				Manufactures. Value.		Guano.			
	Lb.	Metric Tons.	Value.	Value per Met. Ton.			Long Tons.	Metric Tons.	Value.	Value per Met. Ton.
1897.....	406,598	184	$30,167	$163·98	$4,225	$23,438	*Nil.*	.....	.....	.....
1898.....	23,647,968	10,727	1,437,464	134·00	4,687	30,646	*Nil.*	.....	.....	.....
1899.....	2,550,149	1,157	350,919	303·30	10,250	38,393	.....	.....	$8	.....
1900.....	1,281,782	581	212,264	365·19	21,088	38,008	*Nil.*	.....	.....	.....
1901.....	12,888,063	15,823	2,145,468	368·45	9,886	24,080	*Nil.*	.....	.....	.....

Year.	Fertilizers—*Continued.*					Glass and Glassware.	Graphite.			
	Phosphates, Crude or Native.				Other Fert'z's					
	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Value.	Value.	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.
1897.....	65	66	$1,782	$27·00	$3,482	$15,579	128	130	$7,393	$56·87
1898.....	10	10	306	30·12	18,499	13,805	165	168	11,645	69·32
1899.....	723	735	8,718	11·87	4,510	11,179	5	5	338	67·60
1900.....	75	76	386	5·07	31,716	14,614	3	3	115	37·72
1901.....	71	72	1,655	22·99	1,178	16,749	*Nil.*	.....	.....	.....

Year.	Iron and Steel, and Tin Plate.											
	Pig Iron.				Scrap Iron and Steel, fit only to be remanufactured.				Bar Iron, Rolled or Hammered.			
	Long Tons.	Metric Tons.	Value.	Value per Met. Ton	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Lb.	Metric Tons.	Value.	Value per Met. Ton.
1897	114	116	$1,394	$12·00	57	58	$313	$5·40	66,345	30	$1,699	$56·60
1898	581	590	7,008	12·03	63	64	270	4·22	48,151	22	1,648	74·91
1899	597	607	7,908	13·04	195	198	2,671	13·49	85,630	39	3,159	81·42
1900	151	153	6,579	43·00	9,079	9,224	131,241	14·23	107,984	49	2,447	49·94
1901	189	191	6,148	32·19	3,331	3,384	61,663	18·22	149,207	68	7,569	120·14

Iron and Steel, and Tin Plate.—*Continued.*

Year.	Railway Bars of Iron or Steel, or in Part of Steel.				Ingots, Blooms, Slabs, Billets and Bars of Steel, and Steel in Forms, N. E. S.				Sheet, Plate and Taggers, Wire Rod, Wire, and Wire Rope and Strand, Iron or Steel.			
	Long Tons.	Metric Tons.	Value.	Value per Met. Ton.	Lb.	Metric Tons.	Value.	Value per Met. Ton.	Lb.	Metric Tons.	Value.	Value per Met. Ton.
1897	262	266	$11,921	$44·82	15,515	7	$1,728	$246·86	2,446,012	1,109	$68,878	$62·11
1898	140	142	3,479	24·50	100,417	46	3,889	83·24	824,723	374	21,231	56·77
1899	*Nil.*	.....	.....	.....	10,760	5	1,718	350·61	377,403	171	11,148	65·12
1900	*Nil.*	.....	.....	.....	5,349	2	1,342	559·17	468,190	213	11,599	54·56
1901	*Nil.*	.....	.....	.....	4,682	2	1,059	498·58	362,077	164	15,408	93·95

Iron and Steel, and Tin Plate—*Concluded.*

Year.	Tin Plates, Terne Plates, and Taggers Tin.				Manufactures. Value.	Lead and Manufactures of. Value.	Marble and Stone and Manufactures of. Value. (*k*)	Metal Compositions and Manufactures. Value.
	Lb.	Metric Tons.	Value.	Value per Met. Ton.				
1897	2,951,473	1,339	$79,179	$59·21	$165,710	$2,088,923	$15,156	$32,791
1898	899,757	408	22,271	54·59	279,717	2,599,734	5,452	58,810
1899	378,866	172	11,308	65·82	346,795	2,881,641	7,525	57,050
1900	1,038,694	471	37,395	79·39	328,704	3,843,861	5,721	79,216
1901	328,359	149	10,383	69·70	149,771	4,190,525	17,063	35,426

Year.	Oil, Mineral.				Paints and Colors. Value.	Precious Stones. Value.	Salt.			
	Gallons.	Liters.	Value.	Value per Liter.			Lb.	Met. Tons.	Value.	Value per M. Ton.
1897	*Nil.*	.....	.....	.....	$15,473	$26,698	5,074,995	2,302	$10,189	$4·43
1898	3,219	12,185	$486	$0·04	15,854	39,974	4,827,266	2,189	4,751	2·17
1899	150	568	88	·07	12,104	49,256	5,216,112	2,366	9,858	4·17
1900	4,706	17,814	800	·04	13,814	14,169	3,548,734	1,610	3,907	2·43
1901	1,475	5,584	831	·15	17,923	32,607	3,699,411	1,678	7,155	4·26

Year.	Sulphur or Brimstone (Crude).				Tin, in Bars, Blocks, Pigs, Grain or Granulated.				Zinc and M'f'res
	Long Tons.	Met. Tons.	Value.	Value per M. Ton.	Lb.	Met. Tons.	Value.	Value per Met. Ton.	Value.
1897	194	197	$3,962	$20·20	869,929	395	$118,662	$300·97	$2,291
1898	1,414	1,437	31,822	22·14	740,336	336	113,334	337·30	1,536
1899	477	485	10,804	22·29	999,315	453	265,188	585·02	1,604
1900	590	599	13,495	22·53	1,108,124	503	335,377	667·28	3,042
1901	207	210	5,066	24·22	2,103,728	954	562,850	589·46	1,641

(*a*) From *Summary of Commerce and Finance of the United States.*
(*c*) Ore, so called, consisting chiefly of matte.
(*e*) Total exports of coin and bullion; that is, includes both domestic and foreign not elsewhere specified.
(*f*) Only approximately correct. The Bureau of Statistics reports only the value of silver ores exported, but a much larger amount of silver leaves the country in copper matte which is classified as copper ore and no record is kept of its silver contents. The gold in copper matte exported is not included in the exports of gold given in the above table. These figures include ore of both domestic and foreign origin.
(*g*) Including nickel oxide and matte.
(*h*) Includes chlorate, muriate, and nitrate of potash, and all other salts of potash.
(*j*) Reported in bbls. and reduced to gals. at 42 gals. = 1 bbl.
(*k*) Including slate.
(*m*) Calculated at 1 bbl. = 400 lb.
(*n*) Not enumerated.
(*o*) Not reported separately. Included with crude phosphates.
(*p*) Not reported separately. Included with antimony.

NOTE.—N. E. S. signifies not elsewhere specified.

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The
Buyers'
Manual

Preface.

THE advertising pages of the annual volumes of this work will well repay the careful perusal and study of every reader who wishes to be well informed upon the present condition of the mineral industry. They give an admirable and practical insight into the present state of the mining and metallurgic arts, for in them nearly every manufacturer or dealer of note in this country advertises the machines, appliances, and processes which are now in vogue, or which it is sought to introduce; while the names and specialties of the most eminent members of the engineering professions, as indicated in their cards, show the direction of modern mining and metallurgical progress.

These advertising pages are no less important to those who desire a clear knowledge of the means by which this country has come to be far the most important producer of minerals and metals than to those who wish to know where to get that full and reliable information concerning the values of properties, machinery, processes, and products which should precede the investment of capital.

Every country in the world is wisely striving to develop its mineral resources, and to build up its mineral industry, and in all of them this volume, which gives the latest and best practice in every department of the industry, has become indispensable. It is constantly consulted for the best technical skill and the most advantageous machinery and appliances in use. All enterprising manufacturers of such wares appreciate this fact, and know that in no other way can they so effectively bring their goods before those who may need them as through the advertising pages of THE MINERAL INDUSTRY. These pages have become a veritable directory of the best in everything relating to the industry, and American, German and English manufacturers there compete for the orders of the whole world. $1,000,000,000 a year is certainly not an overestimate of the annual expenditure for technical skill, machinery and supplies used in the industry of which THE MINERAL INDUSTRY and *The Engineering and Mining Journal* are not only the chief but the only universal representatives published in any language.

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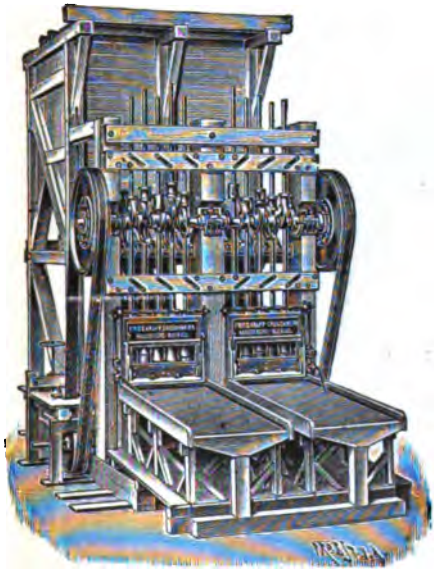

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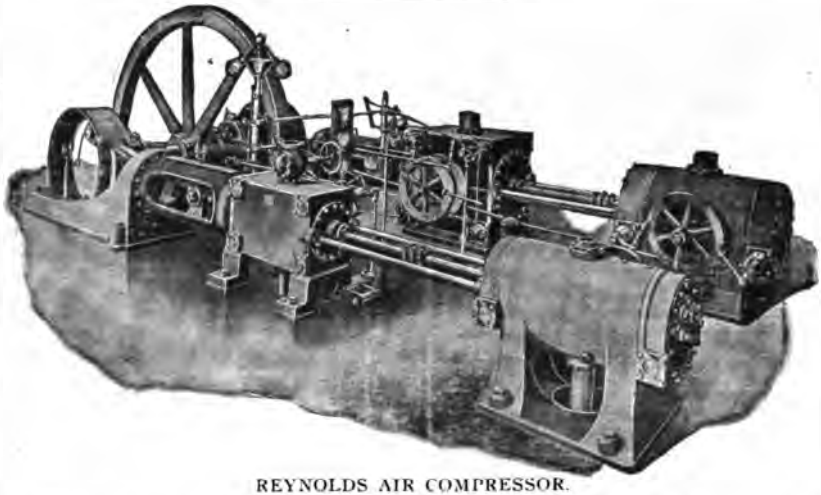

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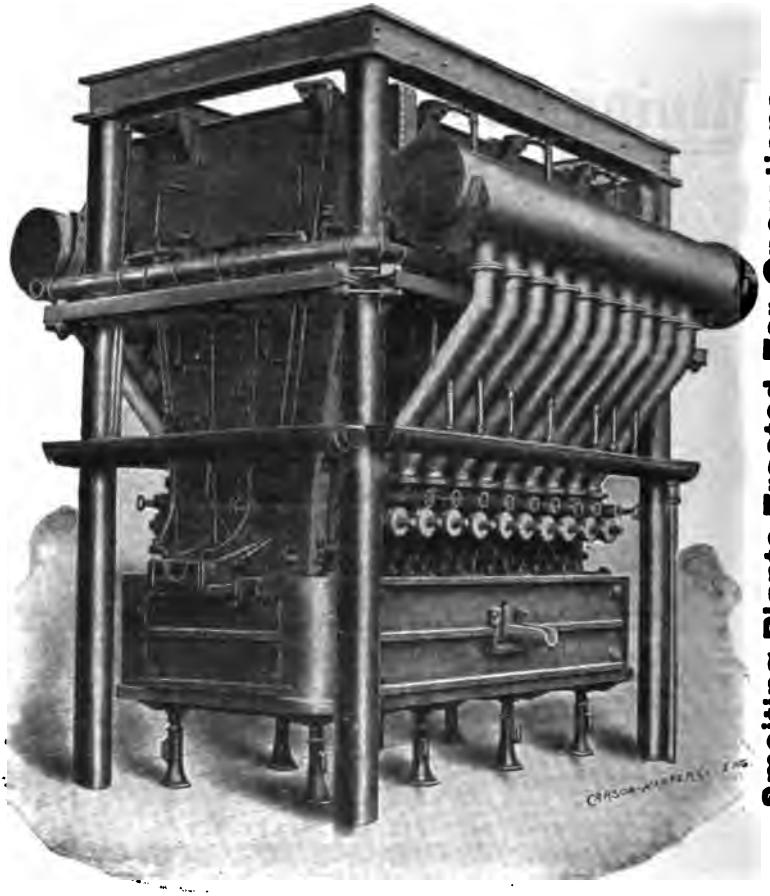

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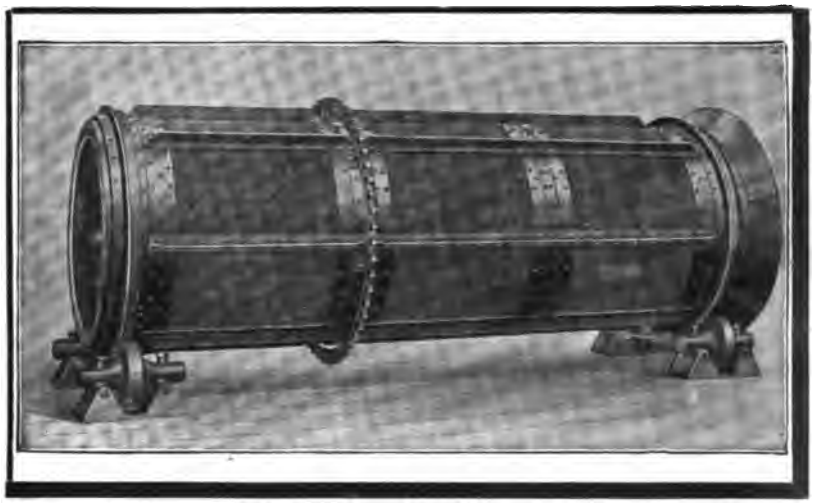

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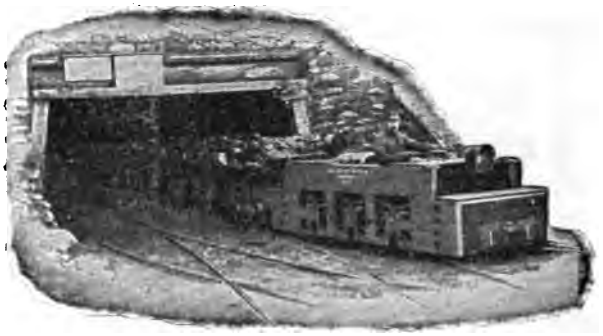

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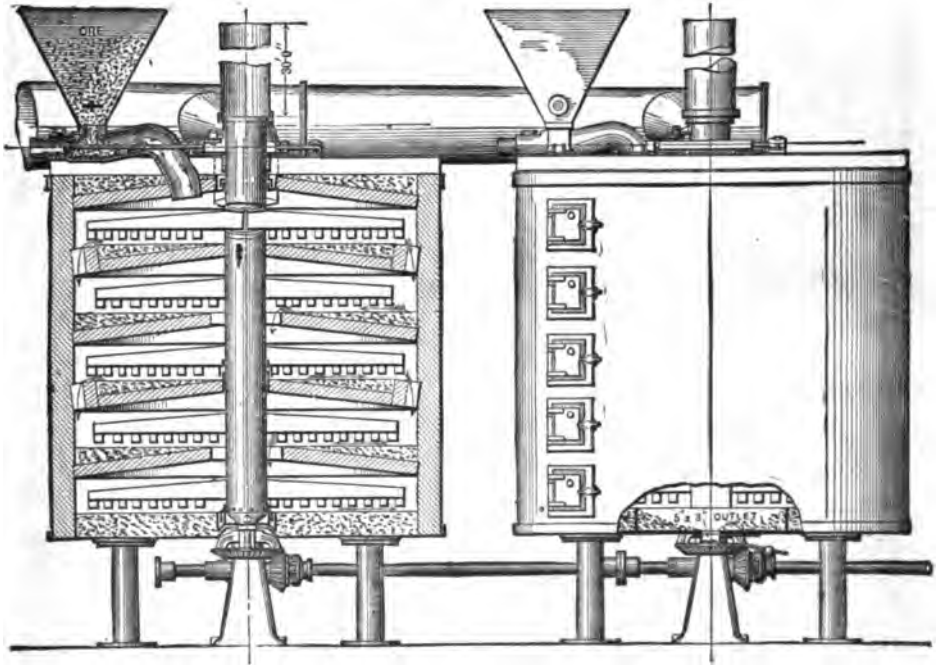

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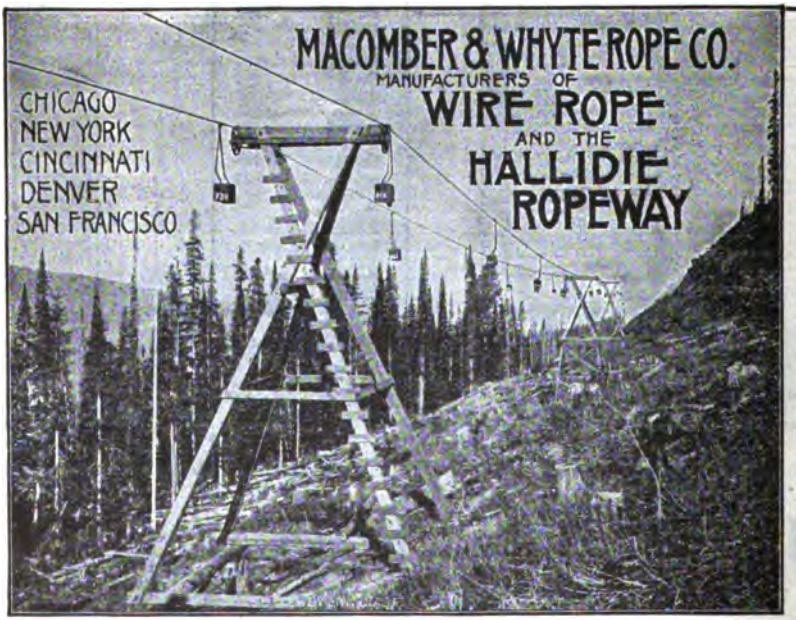

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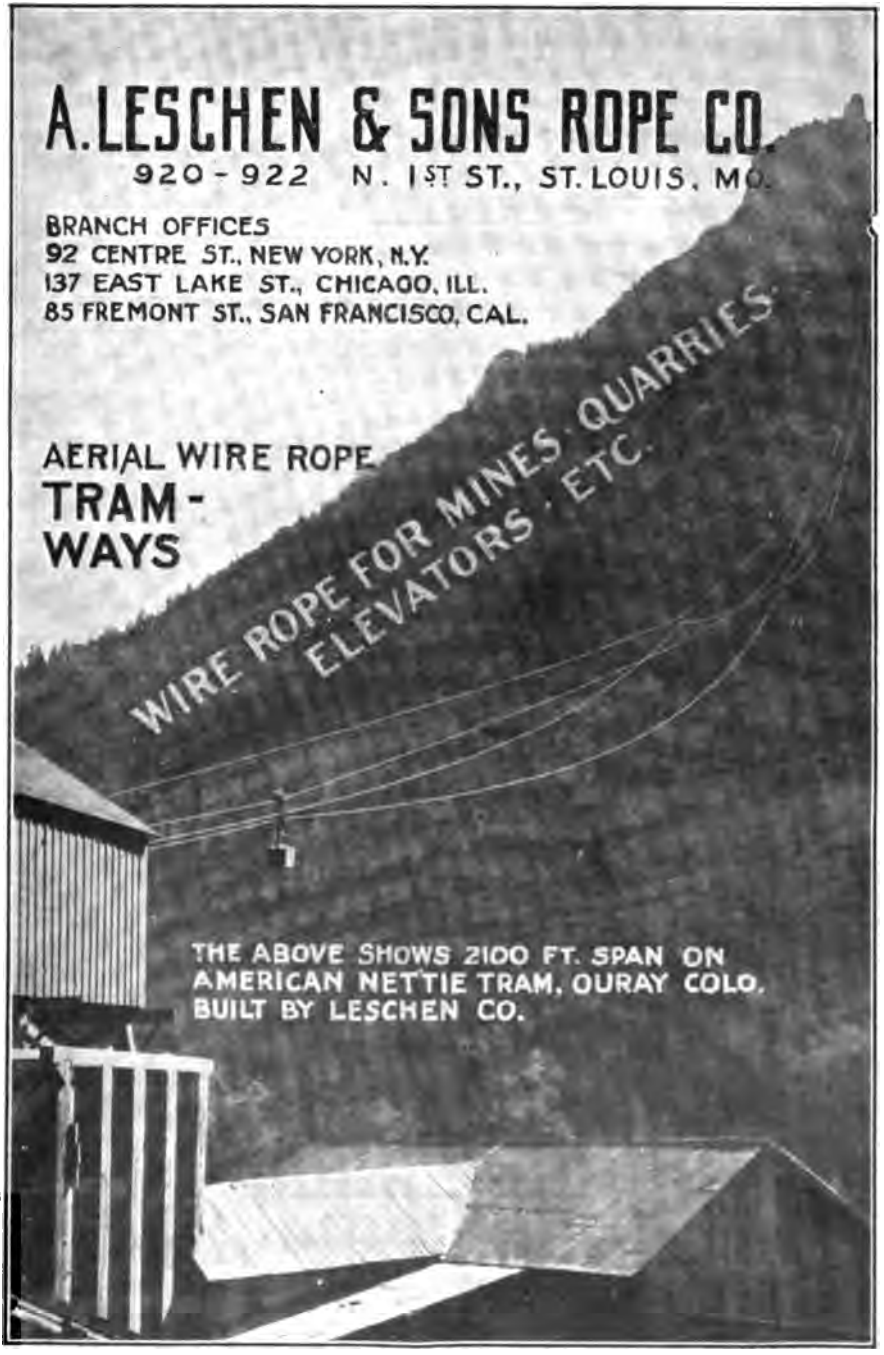
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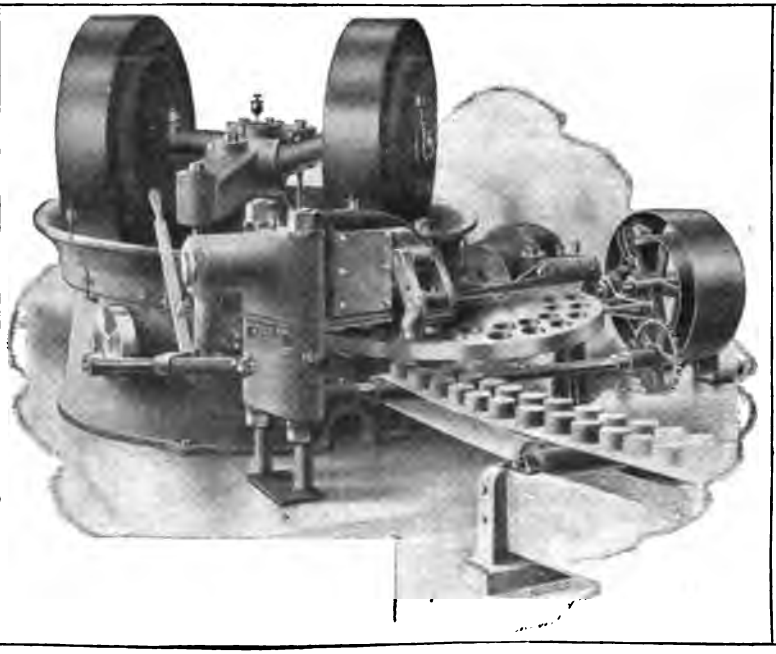

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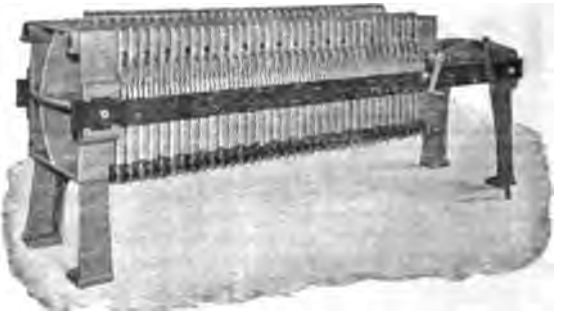

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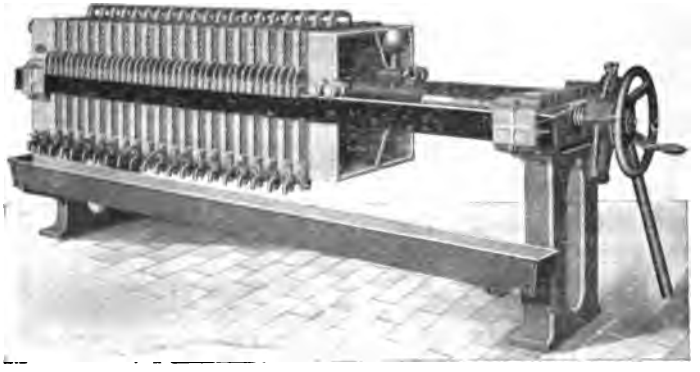

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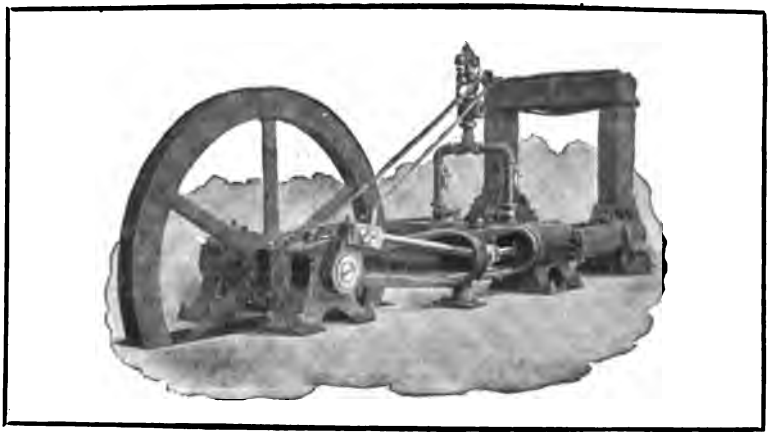

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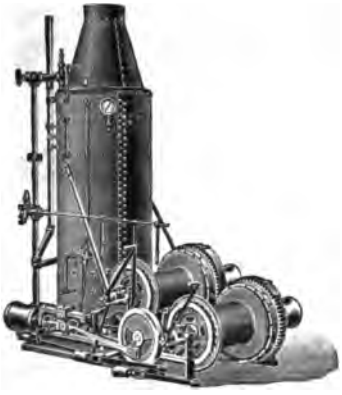

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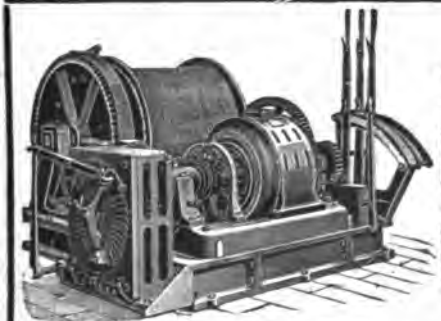

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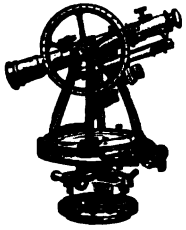

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